

OUT OF THE TWILIGHT ZONE
Portable mind-reader gives voice to the locked in

NewScientist

WEEKLY January 31 - February 6, 2015

HOW PLASTIC
IS RESHAPING THE
ROCKS AND OCEANS

PLASTIC PLANET



THE JOY OF MATH

We lust after proof as much as sex

THAW POINT

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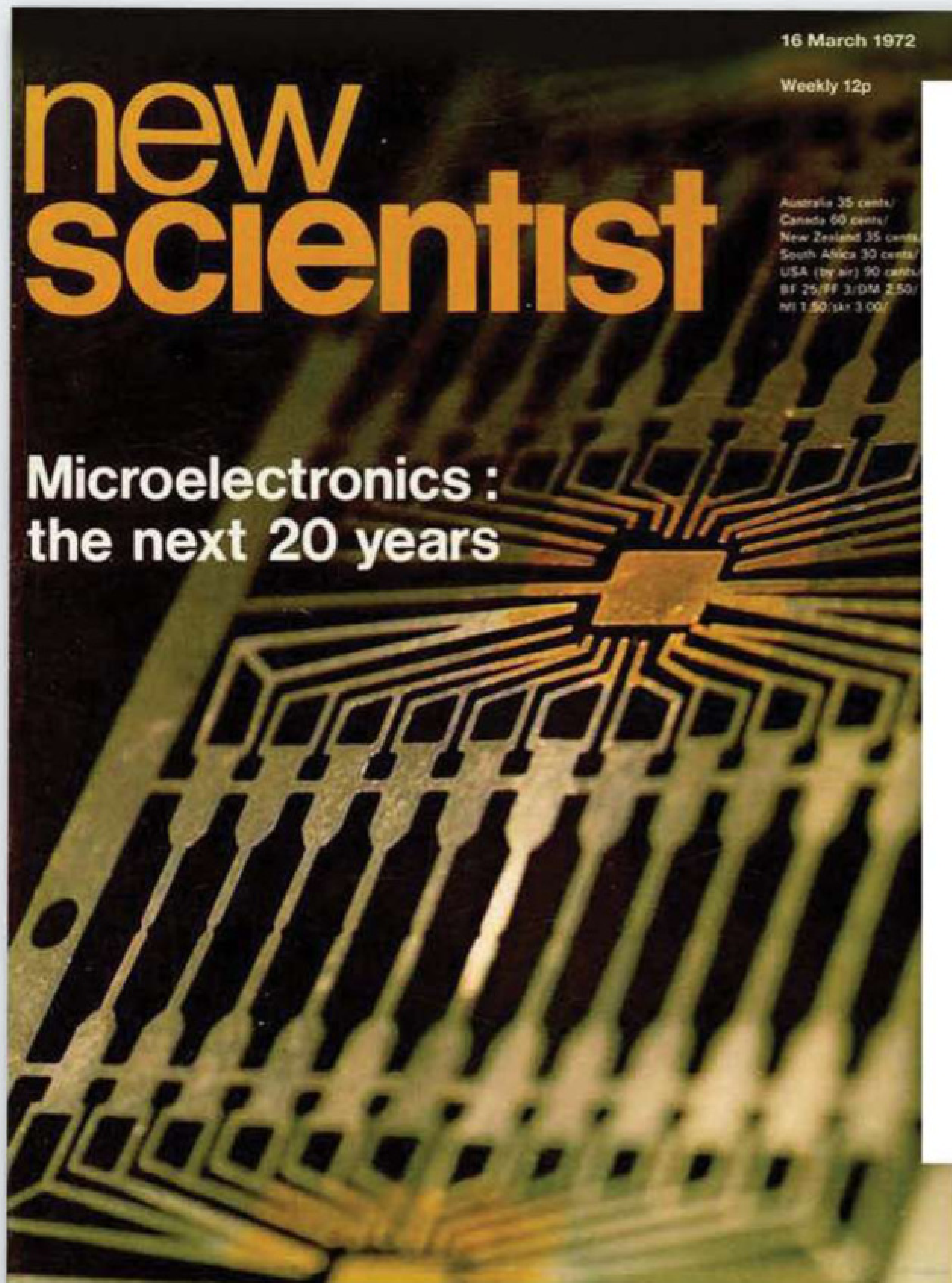


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THE DARK SIDE OF THE MOON

The Apollo 8 astronauts were the first people to see the dark side of the moon with their own eyes. The black ceramic [ZrO₂] Co-Axial Speedmaster salutes the pioneering spirit that took them to a place no human had ever been and it pays homage to the Speedmaster Professional chronographs worn by every Apollo astronaut. OMEGA is a proud partner in mankind's greatest dreams.

For forward thinkers



This elastic market is illustrated by the case for computers in the home. On the one hand are the disbelievers who state that there is only a small range of operations for which the householder will ever need a computer—estimating his taxes once a year, paying bills and balancing budgets once a month and very little else. On the other hand are the optimists who argue that if **microelectronics can make small computers as inexpensive as telephones then people will buy them, even though they are in use for a small fraction of the time. Once in the house, or small office, new uses will be found for them and eventually they will affect life to an even greater extent than the TV set has.** If the optimists are right then the market is huge. Other markets which are waiting to be opened up are ground and air traffic control, process control of all sorts, medical as well as industrial, and on-line reservation systems. Whether or not microelectronics has this particular future depends on improvements in what we already have today—not on new materials, new phenomena, or new structures. However, if one believes in revolution, then materials other than silicon will be used, and other phenomena and structures besides

New Scientist, 16 March 1972

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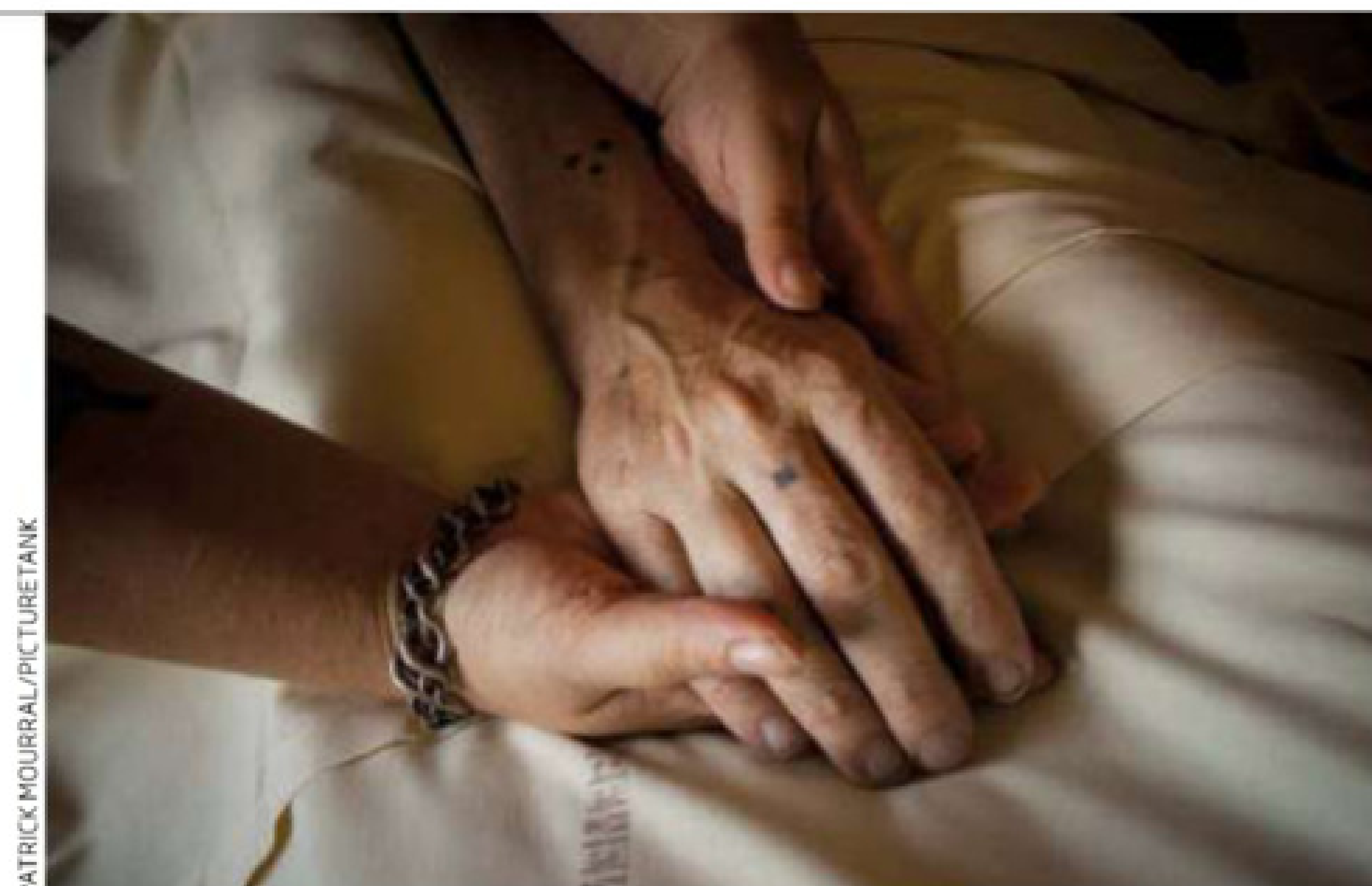
NewScientist

News

8

Mind-reading gets portable

Talking to loved ones trapped in a coma-like state becomes easier



On the cover

28

Plastic planet

How plastic is reshaping the rocks and oceans

- 8 Out of the twilight zone**
Portable mind-reader gives voice to the silent
- 26 The joy of math**
How we lust after proof
- 40 Thaw point**
Antarctica's growing ice
- 35 After the gold rush**
Bitcoin not booming
- 45 None more black**
Making the ultimate portrait of nothing



Cover image
Bernard Pras

Features

40

Thaw point

Why is Antarctica's sea ice still growing?



Coming next week...

Algorithms that run your life

The machines making decisions about you

The world's most hated bird

Why do cormorants get such a bad press?

News

6 UPFRONT

Healthcare paved way for Greek election win. Ebola on the wane. The toll of Brazil's drought. X Prize awards for moon milestones

8 THIS WEEK

Rosetta's summer with a comet. Size isn't everything for mouse testes. Light takes the slow lane. Laser beams caught on camera. The oldest exoplanets. Tree-swingers from 3 million years ago with tools? Stressed immune cells act like antidepressants

11 INSIGHT

Our attitude to sun exposure needs a rethink

16 IN BRIEF

Brain zapping results fizzle out. Supernovae go solo. Pollution linked to strength of polar bear penis bones. ET hunt gets broadband

Technology

- 18** High speed internet beamed in from orbit. Data-crunching to boost blood donations. How to avoid ancient ruins when excavating

Aperture

- 22** A sperm whale "poonado"

Opinion

- 24 Clearing the air** Fred Pearce peers through the global haze over attempts to cut smog
- 25 One minute with... The Duke of Edinburgh** Why engineering matters
- 26 Beautiful seductions** Manya Raman Sundström on an inbuilt drive for math
- 54 LETTERS** Autism and self. Question of time

Features

- 28 Plastic planet** (see above left)
- 35 After the gold rush** Bitcoin's crashed, but fortunes are still being made
- 40 Thaw point** (see left)

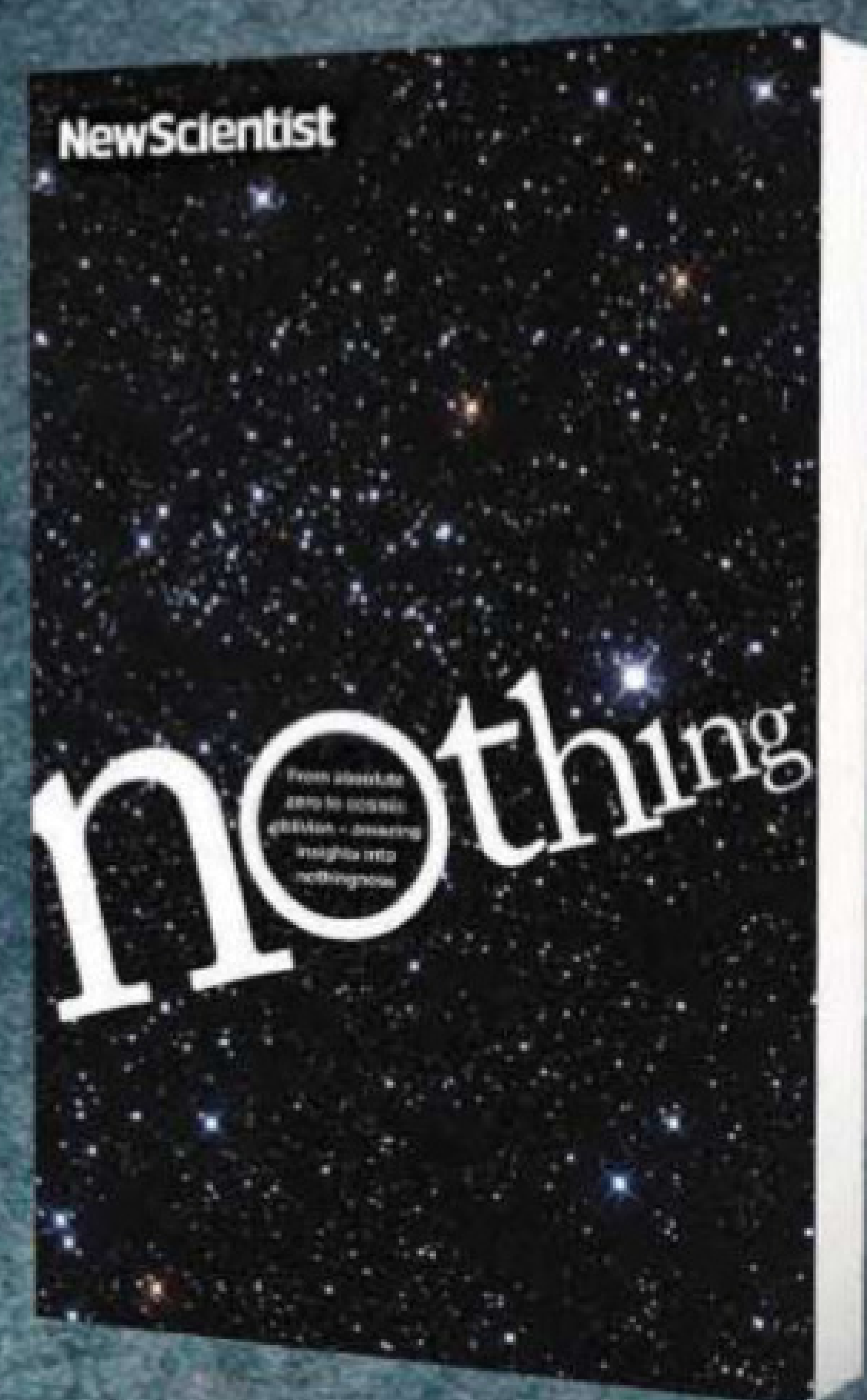
CultureLab

- 44 The greater good** Figuring out what makes us behave selflessly is a complex business
- 45 None more black** Two exhibitions ask what black is all about, and can you paint nothing?

Regulars

- 5 LEADER** The neutrality of the internet is a public good that needs constant defence
- 56 FEEDBACK** Using one fear to hide another
- 57 THE LAST WORD** Ray bands in the sky
- 46 JOBS & CAREERS**

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BILL O'LEARY/THE WASHINGTON POST/GETTY

Long live net neutrality

There's more at stake than the right to make money

FROM its basement beginnings, the internet has spread across the globe. It lets us connect more efficiently than any technology before it, and has become a crucial ingredient of modern life.

One of the keys to its success is "net neutrality" – a jargony way of saying that all internet traffic must be treated equally.

Neutrality has been a guiding principle of the net since its birth, but next month the US Federal Communications Commission will vote on its future in the US. Internet providers largely want to see it end, allowing them to give preferential treatment to traffic from certain websites, or slow down traffic from competitors.

President Obama has advised

the FCC to preserve neutrality, and the smart money is on the status quo. But the fact that the vote is happening demonstrates that net neutrality is a public good that needs constant and vigilant defence against private interests.

Various projects announced last week have the potential to secure net neutrality for years to come. Google, SpaceX and others are racing to provide global, neutral, internet access from space (see page 18). Their projects are welcome not only because they provide alternatives to the existing telecom providers, but because they move the world closer to universal access.

In 1948, the UN published its Universal Declaration of Human

Rights in response to the atrocities of the second world war, many of which were revealed to the world 70 years ago this week.

Among the rights it enshrined were freedom of expression, freedom of thought, freedom of peaceful assembly and the right to education and cultural life. The internet is the most powerful force ever invented to spread those rights.

Those who regard net neutrality as a nuisance should bear this in mind. The newcomers must also avoid the temptation of letting commercial goals override their early idealism. Net neutrality is becoming a human rights issue in its own right. Like the others, it is worth fighting for. ■

Cranking up the heat

LAST year was the warmest on record, even though El Niño failed to show up. Most of the previous hottest years, such as 1998, have come with the warmer sea surfaces that El Niño brings.

If there ever was a warming hiatus, it is over. The long-term trend continues. The world is warming by 0.16 °C per decade.

The effects are evident: record heatwaves, as in Australia, and

record floods – and snow – in many places, with Mozambique and the US the latest to feel the effects. Sea level is rising ever faster. Sea ice in the Arctic is vanishing.

But there's a blip in the big picture. The winter sea ice around Antarctica has grown slightly over the past few decades. It is not clear why (see page 40).

The seas around Antarctica are hard to study, and computer

models are missing some key details. Nonetheless, it is a bit of an embarrassment that climate scientists aren't sure exactly what's going on.

However, it would be wrong to take comfort from this blip – or exploit it to claim that scientists can't get their story straight. In just about every other way, the climate is changing as expected, or worse. This is not a new message, but with crunch UN climate talks coming at the end of the year, it bears repeating. ■



Self-help and Syriza surge

"FISCAL waterboarding." That's how Yanis Varoufakis, Greece's new finance minister, views austerity measures.

As the dust settles after Sunday's elections, which saw the radical Syriza party take power in Greece, self-help groups providing healthcare and other services are springing up across much of Europe in response to cutbacks. They may also be helping to focus voters' attention on parties like Syriza, which have pledged to overturn the European Union's financial reforms.

Led by Alexis Tsipras, Syriza also focused on addressing the needs of millions of Greeks who have fallen on hard times as a result of cuts - which include a 24 per cent reduction in healthcare spending in the five years since 2009.

According to a Greek campaigning group, the Omikron Project, the country now has more than 400 grass-roots groups providing vital services. Around 40 ad hoc clinics are thought to exist throughout Greece, staffed by volunteers and funded by donations. Such clinics have almost certainly helped maintain the health of thousands of Greeks in a country where the unemployment rate is around 25 per cent.

"The volunteer clinics were created to cater to desperate health needs," says Alex Kentikelenis of the University of Cambridge, who has visited some of them. "They're all autonomous and rely on doctors and nurses volunteering their time, and people and pharmacies donating drugs, plus other things like diapers or milk." He says many of the

volunteers are left-wing, as is Syriza.

A lack of data makes it difficult to quantify the clinics' overall contribution, says Kentikelenis. "Forty clinics may not be enough anyway, and they can only provide primary healthcare services. If something's more serious, they probably have neither the staff nor the facilities to deal with it."

Elections are also due this year in Spain, which itself has faced major cutbacks and has its own anti-austerity party, Podemos. Against the backdrop of disillusionment with cuts and mainstream politicians, Helena Legido-Quigley of the London School of Hygiene and Tropical Medicine says that health inequalities will probably translate into support for Podemos, as will the success of Syriza.

Ebola reprieve

THE fight against Ebola has turned a corner. There are now only five confirmed cases in Liberia, the country's government announced last week. Falling infection rates are reported across the region, with new case numbers halving in Sierra Leone every 19 days, and every 10 days in Guinea.

The Liberian reprieve coincides with the shipment of an experimental vaccine developed by GSK and Merck, and could mean that there aren't enough participants for a large-scale trial to assess its effectiveness. "It does seem ironic that the improved response to the outbreak is threatening

"It does seem ironic that improved response to the outbreak is threatening vaccine development"

vaccine development, but it's that improved response that has led to the dramatic decrease in cases," says Jonathan Ball at the University of Nottingham, UK.

Margaret Chan, director-general of the World Health Organization, said on Sunday that the WHO is looking to expand its "surge capacity" - its ability to respond quickly to future crises. "Never again should the world be caught by surprise, unprepared."

UK space telescope

TWINKLE, twinkle little star, we're trying to figure out what your exoplanets are. That's the idea behind a proposed UK-led space telescope called Twinkle that will analyse known alien worlds to better understand them.

There are over 1800 known exoplanets, and both NASA and the European Space Agency plan to launch dedicated planet hunters in 2017 to find more.

But astronomers aren't content to just collect exoplanets, says

Giovanna Tinetti of University College London, they want to know more about them. So she and her colleagues propose Twinkle – so called because it will watch for a dip in light as the planet passes in front of its star – to observe light filtering through known planets' atmospheres to work out what gases they contain.

The spacecraft is being designed by UK firm Surrey Satellite Technology, and a number of UK universities are already on board, but the team is still looking for funding. They aim to launch in the next three or four years – much faster than most space missions.

India sees green

GREEN vision is a go. US president Barack Obama's visit to India this week raised speculation that meaningful action on climate change might be taken at the UN summit in Paris later this year.

The two nations agreed to collaborate on clean technology that could help India cut its huge carbon emissions. India's prime minister Narendra Modi unveiled plans to boost the share of its energy that comes from renewable sources. The aim is to produce 100 gigawatts of power from solar panels by 2022. The country is also considering a target of 60 gigawatts from wind power and expanding its nuclear energy resources.

"We very much support India's ambitious goal for solar energy, and stand ready to speed this expansion with additional financing," said Obama. And India can now also make use of US know-how on nuclear energy.

"Forty per cent of India is still not connected to the grid," says Krishnan Pallassana of the Climate Group, an international think tank. "Clean energy, particularly solar and wind, could eventually connect these homes via renewable sources, and revitalise India's failing energy system."

Moon milestones

IT'S prize money without the prize. The Google Lunar XPrize, a competition designed to encourage private space flight to the moon, has awarded a total of \$5.25 million in "milestone prizes" to five competing teams. The money is intended to help them get off the ground, after the XPrize Foundation repeatedly pushed back the deadline from the original date of 2012.

Astrobotic, based in Pittsburgh, Pennsylvania received \$1.75 million for developing technology for imaging, mobility and landing.

Four other teams picked up prizes in one or two of these categories.

The actual XPrize of \$20 million is for the first team to successfully land on the moon, travel 500 metres and beam images

"Five teams have received 'prize' money to help them get private space flight off the ground"

back to Earth – supposedly before the end of 2016. "Clearly it's very hard to do, but they've not stopped working," says Bernard Foing of the International Lunar Exploration Working Group.

Brazil hit by worst drought in 80 years

LIGHTS out. Brazil's south-east, home to Rio de Janeiro and São Paulo, is facing its worst drought since 1930 and the dry weather looks set to continue. More than 90 cities have imposed water rationing affecting close to 4 million people, according to media reports.

The government has called on Brazilians to cut their water and energy use. "We are living an atypical situation and it is very important that people do their part and avoid the waste of water," the environment minister, Izabella Teixeira, said at a press conference last week.

Low water levels also spell trouble for electricity generation. Brazil relies on hydroelectric power for around 65 per cent of its supply and is now

facing shutdown of some plants. Towns and cities have already been hit by blackouts. "The situation is quite difficult," says Luiz Pinguelli Rosa, director of the Coppe Institute for engineering research at the Federal University of Rio de Janeiro.

Low rainfall is only partly to blame, Pinguelli says. A lack of planning in the energy sector has magnified the problem, he says, as has continuing to run hydroelectric plants despite low water levels – instead of switching to thermoelectric power.

"The only solution in the short term is to reduce the consumption of water and energy." In the long run, Brazil should focus on solar energy, Pinguelli says, but this will need political will and funding.

SEBASTIAO MOREIRA/EPA/CORBIS



Running dry in São Paulo

60 SECONDS

Swap bitcoin for \$

Bitcoin start-up Coinbase has launched the first licensed exchange in the US, in an attempt to help the cryptocurrency go legit (see page 35). Backed by \$106 million from the New York Stock Exchange and other funders, it will let users swap bitcoins for dollars in 24 US states with the blessing of financial regulators.

Good news for tigers...

It's clawback time in India, where tiger numbers have increased by 30.5 per cent since 2010. There are now 2226 tigers, compared with a low of 1411 in 2006. Indian environment minister Shri Prakash Javadekar said the turnaround was down to better forest management and community cooperation.

... but terrible for rhinos

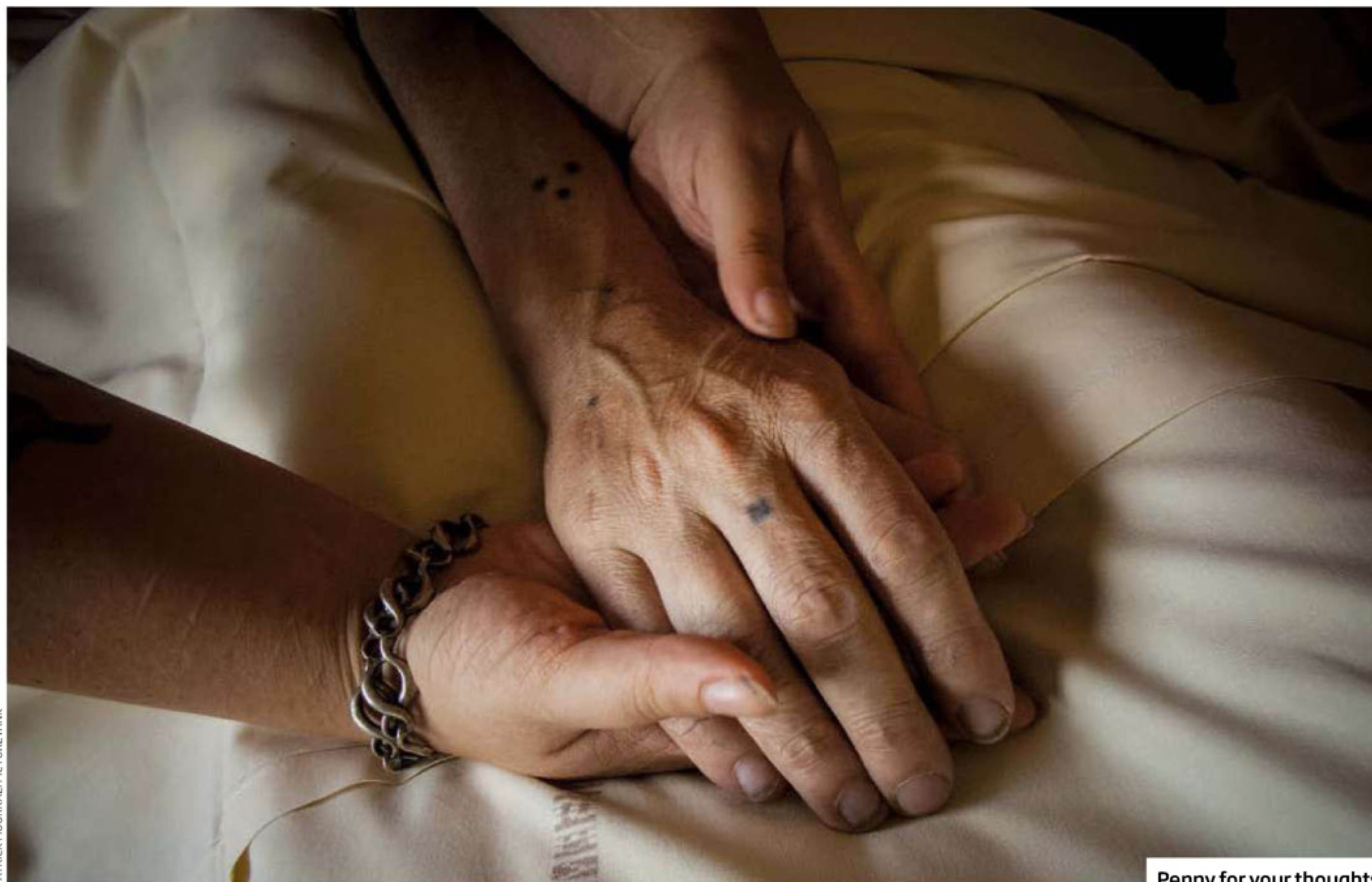
South Africa's rhinos are in trouble. New government figures reveal that a record 1215 rhinos were killed last year, outdoing the 2013 record of 1004. Just 13 were killed in 2007. Wildlife crime charity TRAFFIC says 827 mostly white rhinos were taken from the world's largest population in Kruger National Park, thanks in part to poachers from neighbouring Mozambique.

Asteroid had company

That's no moon! No, wait, it is. Radar images of asteroid 2004 BL86, which passed close by on Monday, revealed the 325-metre-wide rock is accompanied by a 70-metre satellite. The pair came within 1.2 million kilometres of Earth, about three times the distance to our own moon, and won't be back for 200 years.

An egg, unboiled

"We have invented a way to unboil a hen egg." So said Gregory Weiss from the University of California, Irvine, as he described a way to untangle proteins, such as those in egg white, so they can be refolded. The method could be used to recycle proteins in medical and chemical processes (*ChemBioChem*, doi.org/f2zc89).



PATRICK MOURRAL/PICTURETANK

Penny for your thoughts

Mind-reading goes portable

Communicating with people who are locked-in is becoming easier

Clare Wilson

YOU wake up in hospital unable to move, to speak, to twitch so much as an eyelid. You hear doctors telling your relatives you are in a vegetative state – unaware of everything around you – and you have no way of letting anyone know this is not the case. Years go by, until one day, you're connected to a machine that allows you to communicate through your brain waves. It only allows yes or no answers, but it makes all the difference – now you can tell your carers if you are thirsty, if you'd like to sit up, even which TV programmes you want to watch.

In recent years, breakthroughs in mind-reading technology have brought this story close to reality for a handful of people who may have a severe type of locked-in syndrome, previously diagnosed as being in a vegetative state. So far, most work has required a lab and a giant fMRI scanner. Now two teams are developing devices that are portable enough to be taken out to homes, to help people communicate on a day-to-day basis. The technology might also be able to identify people who have been misdiagnosed.

People with “classic” locked-in syndrome are fully conscious but completely paralysed apart from

eye movements. Adrian Owen of Western University in London, Canada, fears that there is another form of the condition where the paralysis is total. He thinks that a proportion of people diagnosed as being in a vegetative state – in which people are thought to have no mental awareness at all – are actually aware but unable to let anyone know. “The possibility is that we are missing people with some sort of complete locked-in syndrome,” he says.

“The possibility is that we are missing people who are fully conscious but can't let anyone know”

Owen's group and others are on a mission to give a voice to as many such people as possible. He is also asking ethicists how to respond if such people, once they can communicate, express a wish to die (see “What if they want to die?”, above right).

People most often enter a vegetative state after emerging from a coma. Instead of fully awakening, they enter a twilight zone between the two states. Their eyes may sometimes open, but their gaze wanders randomly and they do not respond to attempts to communicate, a key measure of consciousness. There is no official tally, but Derick Wade,

In this section

- Rosetta's summer with a comet, page 10
- The oldest exoplanets, page 13
- Stressed immune cells act like antidepressants, page 15

a neurological rehabilitation consultant at Oxford University Hospitals has estimated that there are about 6000 people in the UK in a persistent vegetative state.

Owen's group has previously shown that a proportion of these people can in fact understand and follow instructions. The group made headlines in 2010 when they demonstrated this using an

The team showed in 2011 that three out of 16 people classed as being in a vegetative state could generate discernibly different patterns of brain activity in response to these commands. But Owen thinks this could still miss some people with awareness, as even people without brain injuries find the task difficult: one quarter of healthy volunteers he tested couldn't do it. "It's quite hard to imagine squeezing your hands," he says.

Now he has a new version, which involves placing vibrating devices on someone's arms, and asking them to pay attention to one vibrator or the other as they are asked questions, Owen told the Barts Neuroscience Symposium in London last week.

Focusing on sensory information like vibration seems to be easier to read on an EEG than imagined movements, he says. "Tactile stimulation works very well." Still, it's early days and Owen's work is unpublished as yet. "We have had some successes," is all he will say for now.

Owen has reason for caution as his work is not without its critics. They worry that the publicity surrounding his work is giving false hope to families caring for people who are truly in a vegetative state. They also claim

an fMRI scanner, which shows brain activity. They asked people to imagine they were playing tennis or walking around their home. Not only did the scans show that about one in five of those tested could think about the different activities on cue, but three people so far have been able to use the different patterns of brain activity that these thoughts produced to answer simple yes or no questions.

One man tested, for instance, who had been classed as in a vegetative state for 12 years after a car crash, correctly answered questions about his name and those of his carer and a relative. He went on to signal that he was not in pain – and that he liked watching ice hockey on TV. "They were important questions for his family," says Owen. "It's about quality of life."

Brain scanning is a laborious process, though, so it is no good for helping people communicate frequently or easily. The size and cost of fMRIs mean that most care homes do not have them. To make the technology more accessible, Owen's team has been developing a version of the technique that uses an electrode cap to record the brain's electrical signals, or EEG. Because an EEG can only read surface brain activity, they had to find different mental tasks. Their first approach was to ask people to think about squeezing a hand or wiggling their toes.

WHAT IF THEY WANT TO DIE?

Adrian Owen has not used his methods of communicating with locked-in people (see main story) to ask someone if they want to end their life. "We don't have the [ethical] frameworks in place for dealing with that question," he says. He is, however, working with ethicists to draw up the first set of guidelines for such cases, which he hopes to have ready next year.

Going down this road would not be classed as euthanasia. People who are completely paralysed are kept alive by artificial means. This is classed as medical treatment, and can be refused by anyone who is mentally competent. Treatment can already be withdrawn if a person's relatives think it is what they would

have wanted.

There are well established ways of deciding if someone is of sound mind – but analysing brain activity is not currently conducive to them. "It's like trying to evaluate decision-making capacity in an abbreviated game of 20 questions," says ethicist Andrew Peterson of Western University in London, Canada, who is helping to write the guidelines.

Even with Owen's communication methods, there is likely to be some uncertainty. There will be cases where relatives disagree with the patient or with each other over whether treatment should continue. "This is not going to end up being a medical issue, this is going to end up a legal issue," says Owen.

that the people with whom Owen has communicated had been misdiagnosed and were actually in a minimally conscious state (MCS). Such people can show fluctuating signs of awareness, such as being able to open their eyes on request. If this is true, then they don't need a mind-reader to communicate, just better diagnosis in the first place, to alert carers to ways they could communicate.

Yet Owen insists that his work shows that around 20 per cent of

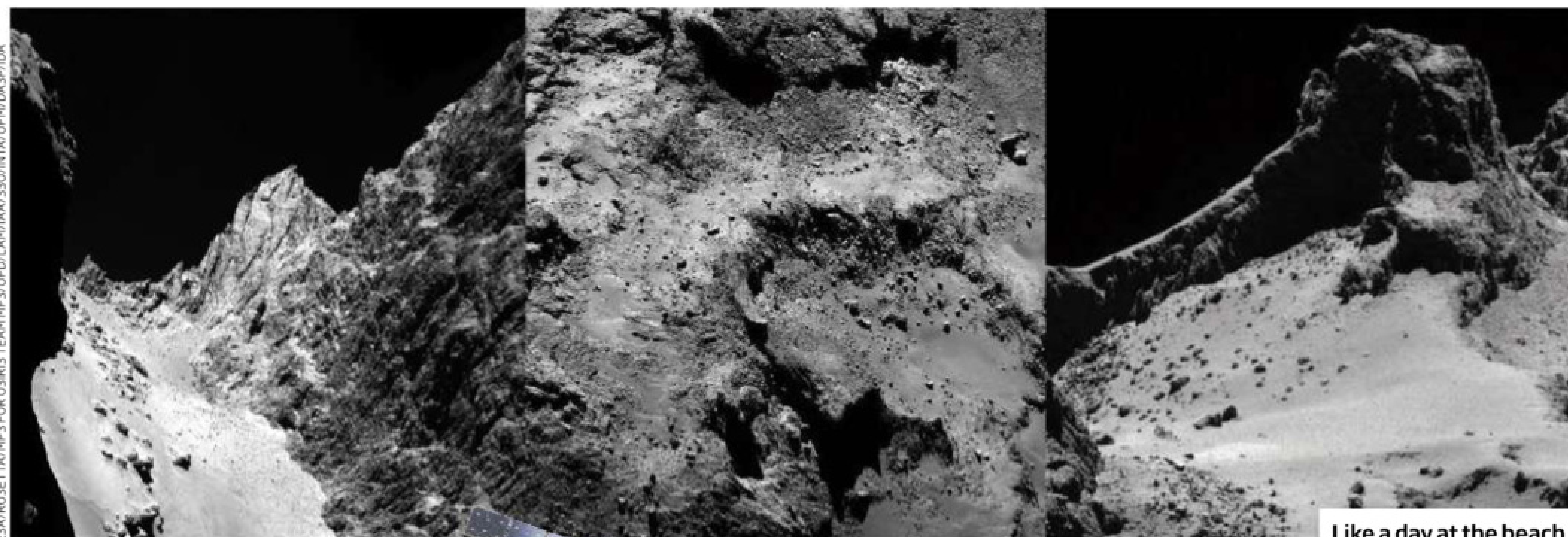
people classed as being in a vegetative state really have some kind of awareness – and that his latest version of the EEG "mind-reader" will help to find them. EEG communication devices already exist for people who have classic locked-in syndrome. They can look at letters as they flash on a screen and select them with a burst of mental activity, picked up by electrodes.

And a company in Austria called g.tec has developed an EEG device using vibrating pads for the wrists for people who have difficulty communicating. It went on sale in Europe at the end of last year. A group led by Steven Laureys of the University of Liège in Belgium has tested it on people with classic locked-in syndrome and found that asking users to count how many buzzes they feel on each wrist helps the electrodes pick up brain activity more clearly, and might make it possible for the device to enable people who are completely locked-in to communicate.

Despite the critics, Owen seems upbeat: "I think we may be able to send people home with some variation of an EEG. We will get there." ■



Brain-wave detector



Like a day at the beach

Summer holiday around a comet

#ROSETTAWATCH

DESPITE the fantastic success of the European Space Agency's Rosetta spacecraft, which has been hanging out around comet 67P/Churyumov-Gerasimenko for over six months, mission researchers had until now released only a few findings.

Now, the team has published seven reports in the journal *Science* covering data from August and September ([doi.org/zns](https://doi.org/10.1126/science.1257501)). Here are our favourite bits:

EGYPTIAN GODS RULE 67P

The comet's duck-like shape makes it hard to use a latitude and longitude system, so the Rosetta team has split the 4-kilometre-long comet 67P into 19 regions named after ancient Egyptian deities, like Seth and Anubis.

PAIN IN THE NECK

The Hapi region on 67P's "neck" hosts the only visible crack in the comet's surface, which is about 1 kilometre long and a few metres wide. An on going mystery is whether the two halves were once separate comets that merged, or a larger comet that eroded slowly.

COMETS HAVE GOOSEBUMPS

Some parts of 67P are dotted with lumps that Holger Sierks, who runs Rosetta's OSIRIS camera, and colleagues call "goosebumps". They may be formed when tiny grains of dust floating in space get drawn together into "pebbles" about 3 metres wide. These pebbles can only grow larger by merging with others, eventually forming a larger body like 67P.

FLUFFY DUCK

New figures for the comet's mass and volume peg its density at roughly 500 kilograms per cubic metre, about the same as cotton wool. This fluffy material is hard to hold onto – 67P loses around 4 billion kilograms, 0.01 per cent of its mass, on each six-and-a-half-year orbit around the sun.

SMELLING OUT THE SEASONS

The comet's rotation gives it seasons. It is currently "summer" on 67P's head, so some parts of the body are in darkness. That means the comet's coma – its transient atmosphere – varies from place to place.

Rosetta's ROSINA spectrometer sniffed the coma and found

higher concentrations of water near the head, and more carbon dioxide around the body. Kathrin Altwegg, who runs ROSINA, says they are still figuring out whether this is because the two halves have a different origin, or because they release different gases seasonally.

DUST IN THE WIND

It was a bit puzzling to find dune-like structures and other features seemingly formed by wind when pictures of 67P first arrived, because its scant atmosphere shouldn't be able to support even a slight breeze. But it seems the low-density gas released by the comet is blowing fast enough to shift tiny particles around. It's also possible that charged dust is being levitated across the surface by low-level electrical fields.

BLACK AS NIGHT

67P reflects just 6 per cent of the sunlight that hits it, so the comet's nucleus is one of the blackest objects in the solar system. This darkness is partly due to its carbon-rich surface, which contains organic compounds like carboxylic acid – found in the amino acids needed for life. Also, Rosetta hasn't seen any reflective icy patches on 67P's surface, meaning the first millimetre or so contains very little water – unsurprisingly, as it probably would have been stripped off during previous passes by the sun.

ALL CHANGE

A paper published this week in the journal *Nature* suggests the comet may be shedding this surface ([doi.org/zps](https://doi.org/10.1038/nature13001)). Remote observations during 67P's last jaunt around the solar system in 2008 suggest that, when it comes within 400 million kilometres of the sun, it starts kicking off its outer dusty layer to reveal a mixture of ice and dust. This probably happened again within the past month. The dust particles Rosetta has collected so far have crumbled after hitting its COSIMA instrument, meaning they don't contain ice. The team is still waiting for new data to confirm the wardrobe change.

FINDING PHILAE

The *Science* papers give no update on attempts to spot the Philae lander, which touched down in November before its batteries died a few days later. But Sierks told *New Scientist* that a dedicated imaging campaign in December was unsuccessful, and Rosetta's busy science schedule leaves no time to search again until May. That's also when 67P's seasons will shift, illuminating the shadowy part of the comet where the probe landed. The hope is that light will fall on Philae's solar panels, letting it reactivate and resume contact. But even if the lander slumbers on, the view of 67P's dark side is something to look forward to, Sierks says. **Jacob Aron ■**

INSIGHT Sunshine guidance

Soak up the sun, just don't get burned

WE MIGHT be in the middle of the British winter but I'm already thinking about summer. As a parent, the arrival of summer has its own rituals: stocking the freezer with ice lollies, unearthing the paddling pool – and bracing myself for the usual onslaught from the sunshine police.

First come the newspaper articles claiming we must not only cover up our flesh, but that we must do so with special, tightly woven fabrics, and preferably stay indoors between 11 am and 3 pm. Then come the letters from school insisting that all pupils wear hats and be lathered in sun cream.

But the tide seems to be turning. The UK's National Institute for Health and Care Excellence (NICE) thinks we need to change our attitude to sunshine. Sunlight is essential for our skin to make vitamin D, so it has health benefits as well as risks, according to the agency's latest draft guidelines on sun exposure. Having weighed all the evidence, the authors conclude that as long as people don't get sunburned, we should be actively trying to soak up the rays.

"It's revolutionary," says Michael

Holick of Boston University, a long-time proponent of the benefits of sunshine.

The UK's sun phobia was triggered by rising rates of skin cancer in Australia, a nation that gets a lot more UV than these shores. But then came a resurgence of rickets among UK

children, especially in people with darker skin. Vitamin D is needed for strong bones, so children who don't make enough become bow-legged.

But rickets is only the earliest and most obvious sign of vitamin D deficiency. It also causes problems with the immune system, possibly leading to the autoimmune disease multiple sclerosis in later life, and makes us more susceptible to cancer. So although skin cancer rates are higher in those who get more sun,

other kinds of cancer are lower, including colon, breast and prostate cancer.

Because of this research, I have been among those who flout the advice, even for my children – while making sure we don't get burned, of course. I cheered in 2010, when several doctors' groups spoke out against shunning the sun completely, although they still recommended that people should limit their daily exposure to "a matter of minutes".

The latest NICE guidance goes further, saying that for adults, the chief constraint should be avoiding sunburn. For children the authors are more cautious. On the one hand they say children should stay in the shade when UV levels are high. On the other, however, they talk about explaining to children that sunshine has benefits as well as risks and that skin type affects how much sun you can take. The guidelines specifically warn against cancer scaremongering, saying that: "A skin cancer prevention campaign should also mention the risk of underexposure".

"At least," says Julia Pakpoor, a vitamin D researcher at the University of Oxford, "they are a step in the right direction." Schools, please take note. Clare Wilson ■



Topping up on vitamin D

Forget size – it's what's inside that counts

SIZE isn't everything. Big testes are usually a telltale sign of strong sexual competition between males. But it seems mice can quickly evolve testes that produce more sperm without growing larger.

When many males mate with a female, their sperm compete with each other to fertilise her eggs. Having larger testes allows males to produce more sperm as they bid to pass on their genes. "There is often a raffle element to fertilisation," says

Stuart Wigby at the University of Oxford. "If you buy more tickets, you're more likely to win."

Renée Firman at the University of Western Australia in Perth and her colleagues had previously found that, when mice evolve with high sperm competition, the males produce more sperm – but without developing bigger testes. "We were wondering how the mice had increased their sperm production in the absence of a change in testes size," says Firman.

Studies by researchers like Stefan Lüpold of Syracuse University in New York and his colleagues had suggested that species under intense sperm competition have more sperm-producing tissue. But these

studies only showed a correlation between sperm competition and the density of sperm-producing tissue, and couldn't prove that one leads to the other.

To test what was happening in mice, Firman's team allowed them to evolve in two different mating systems: a monogamous system in which males did not have to compete for females, and a polygamous one, in which males all mated with the same group of females. Just 24 generations later, testes from polygamous males

"There is a raffle element to fertilisation. If you buy more tickets, you're more likely to win"

contained more sperm-producing tissue than those of monogamous males (*Evolution*, doi.org/10.1111/evl.12111).

Lüpold says this is the clearest evidence so far that the level of sperm competition can affect the architecture of testes, and do so in such a short time. "This shows that size isn't everything," says Wigby. He points out that blue whales have bigger brains than humans, but aren't more intelligent.

The findings are unlikely to overturn our understanding of sperm competition and testes size, Wigby says. "Overall, you'd still expect bigger testes in species or populations with much more sperm competition." Penny Sarchet ■

Shapely light likes to take it slow

Jacob Aron

ANYONE struggling with a New Year's fitness regime knows that you move more slowly when you're out of shape. Now it seems the same is true for light, which until now was thought to travel at a constant speed.

It's well known that light travels at different speeds as it passes through different materials; it travels more slowly in water than air, for example. But the speed of light in a vacuum, at a little under 300 million metres per second, is an unwavering constant that underpins much of modern physics, including Einstein's theory of special relativity. It's so important that physicists give it a special letter: *c*.

Now, Miles Padgett at the University of Glasgow, UK, and his colleagues have shown this isn't quite right. Light travelling in a plane wave – the traditional up-and-down squiggle you learn about in school – always travels at *c*, but light with a more complex wave structure travels

slightly slower, by about one-thousandth of a per cent.

The team revealed this oddity by studying two kinds of shaped light: a Bessel beam, which looks like concentric rings of light, and a Gaussian beam, which spreads

out as it travels. They used an ultraviolet laser to produce pairs of photons and passed one photon through a filter to shape it into either a Bessel or Gaussian beam. Both travelled 1 metre before hitting a detector, so they should have arrived at the same time, but the shaped photon was a bit delayed (*Science*, doi.org/znr).

Why does this happen? One way of thinking about it is that some of the light in a structured beam is

moving in the “wrong” direction – sideways rather than forwards. This isn't a strictly accurate picture of the energy distribution within the beam, warns Padgett, but it is a way to imagine what might be going on.

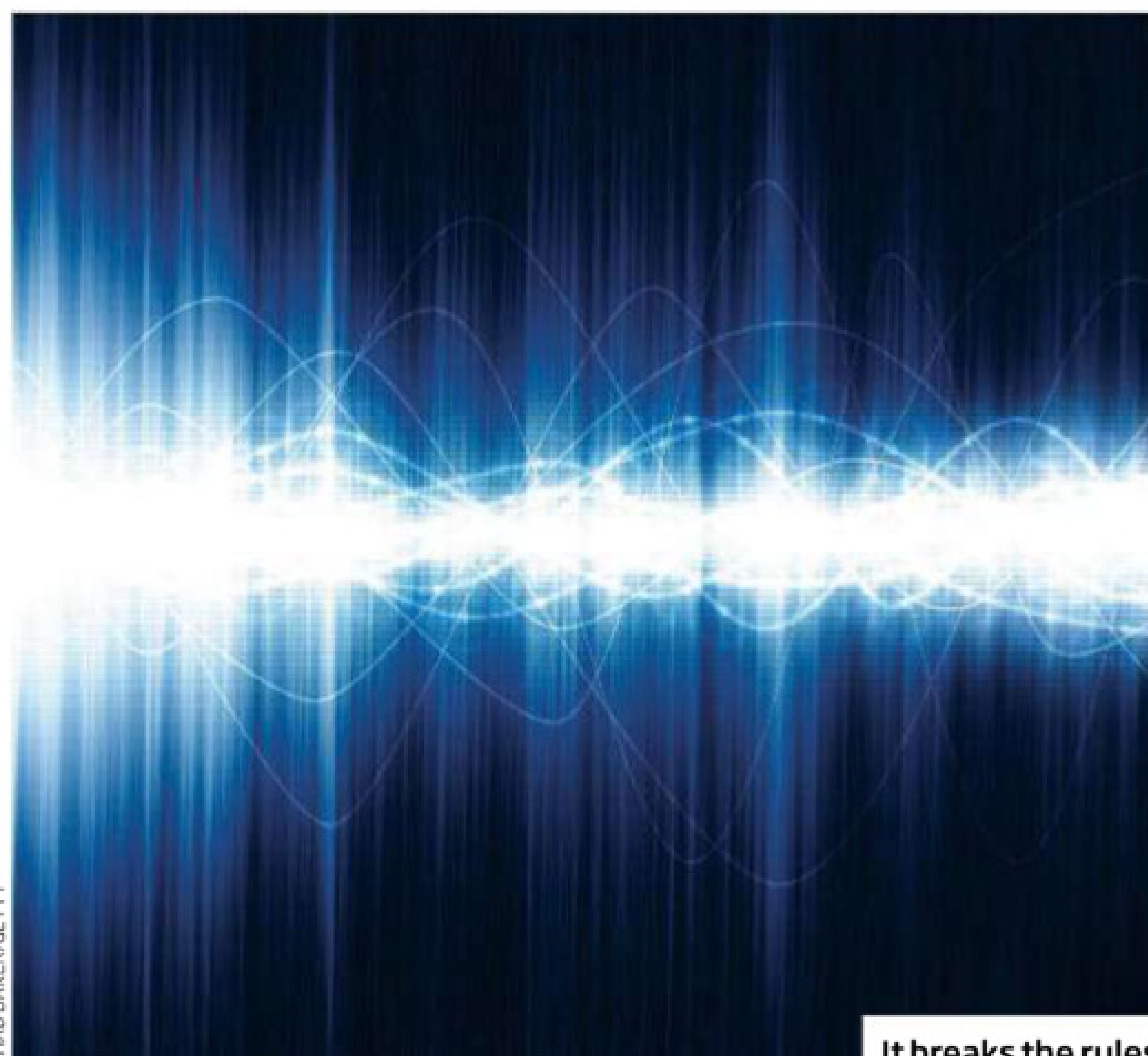
“Personally I think that's a useful concept, though the scientific rigour police might not welcome it,” he says.

Don't rip up your physics textbook just yet, though – the implications are likely to be minor, for now at least, only affecting things like short-range experiments that rely on very precise time-of-flight measurements. “We're not challenging Einstein,” says Padgett.

Hints of this effect have been seen in other experiments, but no one had quite pinned it down before, says Ulf Leonhardt at the Weizmann Institute of Science in Rehovot, Israel.

“[This] is really the first clean and clear experiment where the speed of photons in structured light beams is directly measured,” Leonhardt says. Now that physicists understand it, they might be able to exploit it.

“I do not foresee immediate applications in the short run, but important fundamental physics always has implications and applications in the long run.” ■



CHAD BAKER/GETTY

It breaks the rules

First film of laser's path in mid-flight

PEW pew! That's the welcome sound of the first video of a laser beam in flight.

Watching lasers fly through the air makes for dramatic battles in sci-fi films, but they're not so easy to see in real life. To observe a laser, photons from it must directly hit your eyes. But laser photons travel in a tightly focused beam, all heading in the same direction. This means you can only see them when the laser hits something that reflects a portion of the light and produces a visible dot.

A few photons scatter off air molecules, but normally these are too faint to see. You can get around this by firing a laser through smoke, giving the photons more molecules to scatter off – but that's not the effect we see in the movies.

“The challenge was to have a movie of light moving directly in air,” says Genevieve Gariepy of Heriot-Watt University in Edinburgh, UK.

She and her colleagues constructed a camera sensitive enough to pick up those few scattering photons. It is built from a 32 by 32 grid of detectors that log the time a photon arrives at them with incredible precision, equivalent to snapping around 20 billion frames a second.

The team arranged the camera to film a side-on view of a green laser firing at an arrangement of mirrors. By firing 2 million pulses over a 10-minute period and subtracting background noise, they were able to build up enough air-scattered photons in the camera to track the laser's path as it bounced.

“What comes out is a frame by frame of the light moving through our system,” says Gariepy (*Nature Communications*, DOI: 10.1038/ncomms7021).

“Normally you can only see a laser when it hits something that reflects a portion of the light”

The experiment started as a pure research challenge, but Gariepy thinks the camera could have practical applications. In another experiment, the team filmed a focused laser that ionised air molecules to produce a plasma. Gariepy says a similar setup could help people studying the properties of such plasmas.

Precise timing data could also be used to measure the distance photons have travelled, an effect previously exploited to take pictures around corners. Normally this takes about an hour, but the ability to take multiple images rapidly could generate movies from around corners. “With our camera this can be done in seconds.” Jacob Aron ■

Oldest planets in galaxy raise hopes of alien life

THE Old Ones were already ancient when Earth was born. Five small planets orbit an 11.2-billion-year-old star, making them about 80 per cent as old as the universe itself.

"Now that we know that these planets can be twice as old as Earth, this opens the possibility for the existence of ancient life in the galaxy," says Tiago Campante at the University of Birmingham in the UK.

NASA's Kepler space telescope spotted the planets around an orange dwarf star called Kepler-444, which is 117 light years away and about 25 per cent smaller than the sun.

Orange dwarfs are considered good candidates for hosting alien life because models say they can stay stable for up to 30 billion years - Earth and the sun are only around 4.6 billion

years old. Since we think life begins by chance, the older a planet is the more time life would have to get going.

Kepler-444's planets range from 0.4 to 0.74 times Earth's radius. Because planets tend to be rocky when they're smaller than 1.7 Earth radii, and gaseous when they're bigger, that makes these worlds almost certainly rocky. But they orbit scorchingly close to the star, making them uninhabitable: the furthest, Kepler-444f, orbits once every 9.7 days. The length of their orbits are all multiples of each other, meaning they eclipse each other regularly and every so often line up in a row.

"If you are standing on the surface of the outermost planet, at some points you could look in the direction of the star and see all the other four



IAU/L. CALCADA

It's a rocky road to life

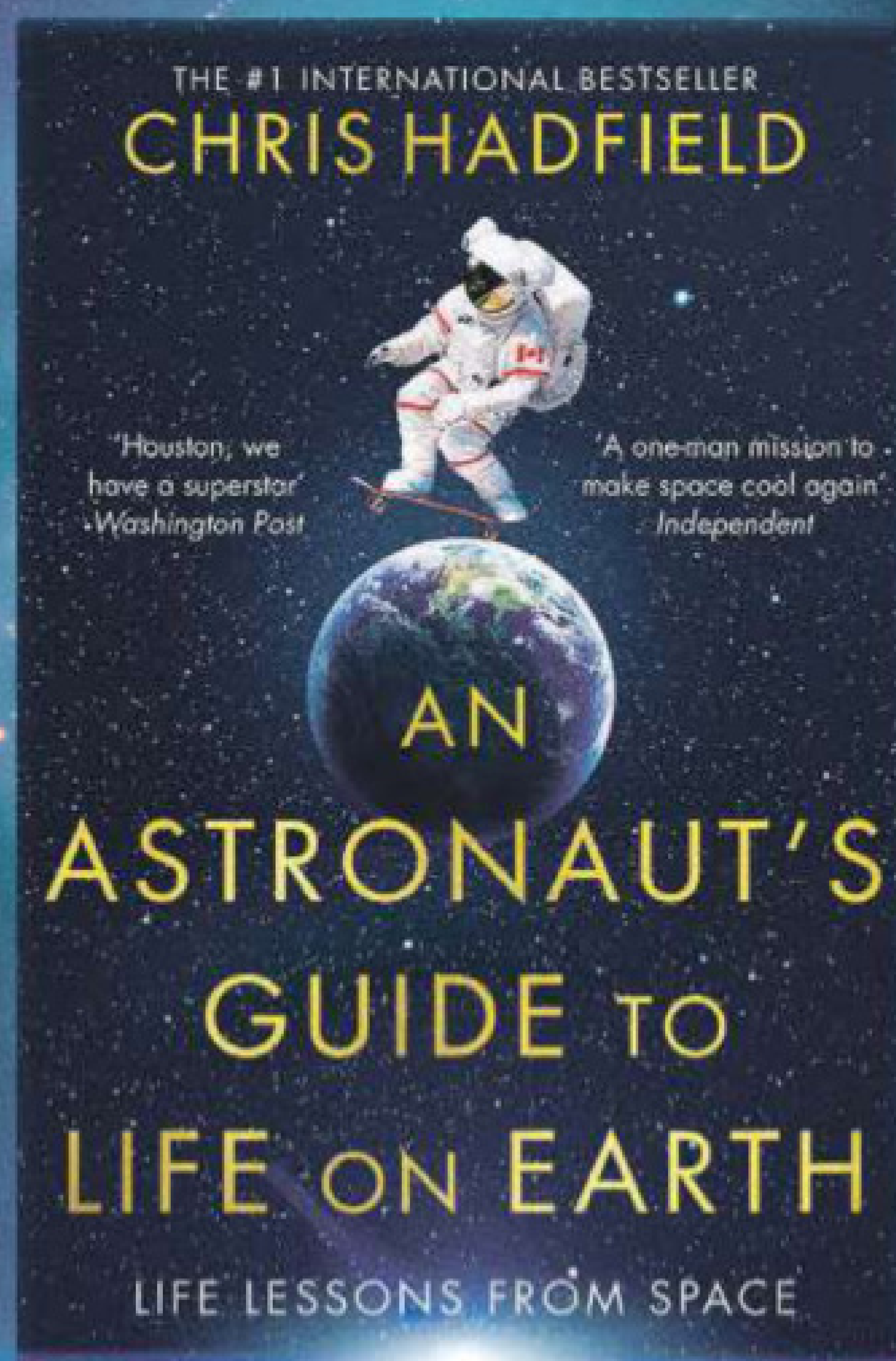
planets aligned," Campante says. "It must be amazing." The team used a technique called astroseismology to measure the star's age at 11.2 billion years, plus or minus 1 billion years. That makes it the oldest known system with terrestrial planets in the galaxy (arxiv.org/abs/1501.06227).

While Kepler-444's planets are too hot for life, its age suggests there

might be cooler, older worlds elsewhere, says Travis Metcalfe at the Space Science Institute in Boulder, Colorado. "If life needs a long time to develop or lots of places to try to develop, having rocky planets this early in the history of the galaxy means planets with advanced civilisations should be everywhere."

Lisa Grossman ■

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The quiet rise of the first toolmaker

Catherine Brahic

MOVE over *Homo habilis*, you're being dethroned. It seems our "handy" ancestor wasn't the first to use stone tools. In fact, the apelike *Australopithecus* may have figured out how to handle them before modern humans evolved.

TOOLMAKING TIMELINE

3.4 MILLION YEARS AGO

Where: Dikika, Ethiopia

Species: *Australopithecus afarensis*

Evidence: Marks on animal bones suggest two types of tools: a stone with a sharp edge that was used to cut and scrape, and a blunt tool that was used to crack the bones open and extract their marrow. But this is controversial as no one has found stone tools this old - yet.

2.8 - 2 MILLION YEARS AGO

Where: South Africa

Species: *Australopithecus africanus*

Evidence: The shape of soft bone tissue in hand fossils suggests their owners had a tool-user's grip (see main story). Still no tools found.

2.6 - 2.5 MILLION YEARS AGO

Where: Gona, Ethiopia

Species: Unknown

Evidence: The oldest undisputed stone tools are typical "Oldowan" style: hammerstones that were used to crack hard objects, and stones that have been knapped to produce a sharp edge.

2.5 MILLION YEARS AGO

Where: Bouri, Ethiopia

Species: Unknown, possibly *Australopithecus garhi*

Evidence: Cut marks and hammerstone fractures on animal bones suggest ancient humans were scraping and breaking them using stones.

One of the first hints of this came in 2010, when German researchers working in Ethiopia discovered markings on two animal bones that were about 3.4 million years old. The cut marks had been made with a sharp stone, and the bones were at a site frequented by Lucy's species, *Australopithecus afarensis* (see timeline).

But that study, led by Shannon McPherron of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, was controversial. The bones were 800,000 years older than the oldest uncontested stone tools, and at the time few thought that australopithecines had been tool users. Plus, McPherron hadn't found the tool itself.

The problem, says McPherron, is that if we just go on tools that have been found, we must conclude that one day somebody made a beautifully flaked Oldowan hand axe, one of the oldest tools known, completely out of the blue. That is unlikely.

Now Matthew Skinner at the University of Kent, UK, and his colleagues have taken a different approach to dating tool use: looking at the hands that held them. Specifically, they looked at metacarpal bones – the five bones in the palm of the hand that articulate the fingers. Because the bone ends are made of soft, spongy bone tissue, they are shaped over a lifetime of use and moulded by what a hand does.

A chimp, for instance, spends a lot of time swinging from branches and knuckle-walking, which exerts a great deal of force on the joints in its hands. Skinner and his colleagues predicted how this should shape the soft bone in ape hands, then looked at modern ape bones, finding their



When did our ancestors first grip?

predictions were right.

Modern human metacarpals look different because we use our hands differently. Most of our activities involve some kind of pinching – think of how you hold a pen. This precision squeeze between thumb and fingers is uniquely human and a legacy from our flint-wielding ancestors.

When Skinner's team looked at the metacarpals of early human species and Neanderthals – who also used stone flakes for tasks like

"A. africanus were tree swingers but they also pinched small objects, suggesting they had tools"

scraping and butchering – they found bone ends that were shaped like modern human bones, and unlike ape bones.

Finally, they looked at metacarpals from four individuals of our ancestor *Australopithecus africanus*, which are up to 2.8 million years old (pictured). They revealed those individuals had been tree swingers but had also spent a lot of energy pinching small objects, suggesting they were indeed early tool users (*Science*, doi.org/znm).

"This study is really interesting because it shows how the hand was actually used, and that's consistent with stone tool use," says McPherron.

The similarities between *A. africanus* and human bones are relatively convincing, says John Hawks of the University of Wisconsin-Madison. "The best explanation is that the difference reflects some powerful thumb-to-finger gripping," he says.

Whether that grip was used to manoeuvre delicate flakes of flint remains to be seen. It's possible *A. africanus* used other types of tools, like bones or pieces of wood. Or they might have been using their precision grips to get at food, such as peeling tough skins off fruit – a task that chimps tend to do with their teeth.

But the study does suggest that 3 million years ago – 400,000 years before the oldest known hand axes – *A. africanus* was already starting to use its hands differently to its ancestors. They were more dexterous and more precise. Whether or not their hands were already wrapped around flints, they were at least laying the foundations for their descendants to do so. ■

How ironic: eau de stress can be an antidepressant

WHAT doesn't kill you makes you stronger, at least when it comes to stress and immune cells. Mice that received a cocktail of immune cells from bullied mice appeared to experience a mood boost. The unexpected discovery may have implications for treating depression.

We know that prolonged bouts of stress take their toll on the immune system. That leaves us susceptible to illness, which in some cases can lead to depression.

Most research on the link between immune health and mood has focused on the innate branch of the immune system - the cells that mount the first response to pathogens, says Miles Herkenham at the National Institutes of Health in Bethesda, Maryland. His team wondered if there might also be a role for the adaptive branch of the immune system, which "learns" about a pathogen in order to respond rapidly the next time it appears.

To find out, the team introduced an aggressive competitor mouse into the cages of male mice. "These mice are like bullies," says Herkenham. Two weeks later, the bullied mice seemed depressed: they cowered in dark corners and seemed uninterested in the scent of a female.

The team extracted their adaptive immune cells and injected them into another set of mice bred to lack these cells. This meant that the recipient

mice essentially acquired the adaptive immune system of the bullied ones.

If anything, Herkenham thought the recipients would become depressed, too. But the opposite happened: the cells appeared to have "antidepressant-like effects", he says. The mice spent more time exploring

open areas and were more interested in females compared to similar mice that didn't receive the injection (*Journal of Neuroscience*, DOI: 10.1523/jneurosci.2278-14.2015).

The team also injected the cells into a strain of mice known for their unresponsiveness. "These mice are rarely used in research because they don't do anything - they just sit in a corner," says Herkenham. The mice were soon running around, exploring their surroundings with abandon.

"It was like a personality change," he says.

Herkenham thinks that adaptive immune cells may cope with stress by building up a sort of mood-boosting resilience, although he doesn't know how this happens. What's unclear is why the donor mice didn't eventually become better at coping with their bullies, and why chronically stressed people often have weak immune systems.

In these cases, the adaptive immune system appears to be held back from exerting its beneficial effects - and the innate branch of the immune system may be to blame, says Herkenham. It's already known that

"The two arms of the immune system are in effect battling it out to dominate our mood"

mice which receive a transplant of cells from the innate immune system can show symptoms of anxiety and depression. Perhaps the two arms of the immune system are in effect battling it out to dominate mood.

George Slavich at the University of California, Los Angeles, says it would be premature to call the adaptive immune system "antidepressive". "The immune system is extremely complex and these two branches interact in many ways," he says.

The team now hope to disentangle what is going on and explore whether reprogramming adaptive immune could hint at a new treatment for depression. Jessica Hamzelou ■



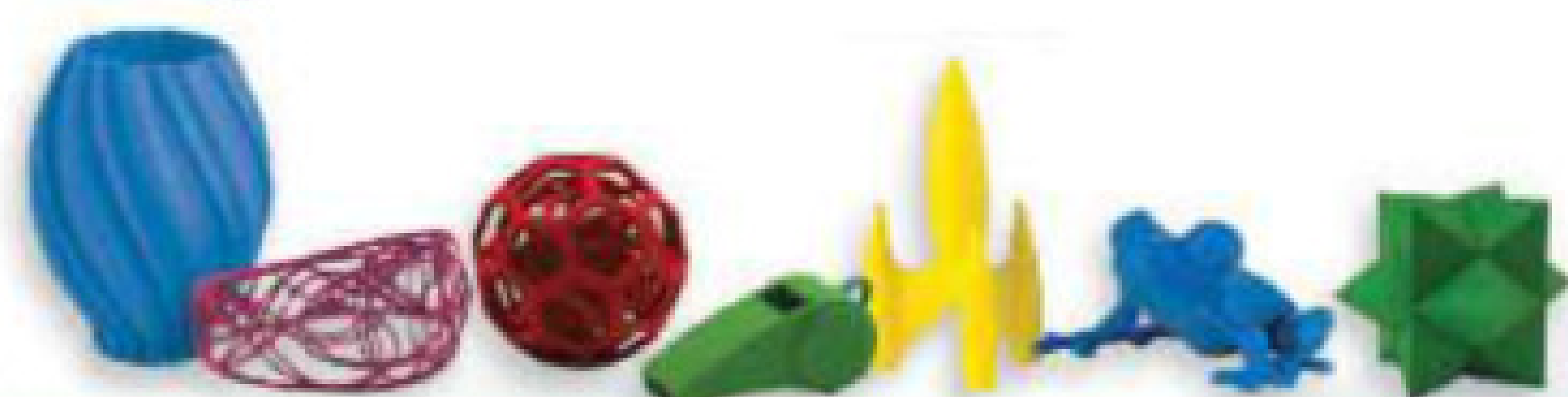
MIKAEL ANDERSSON/PLAINPICTURE

Resilience is the reward

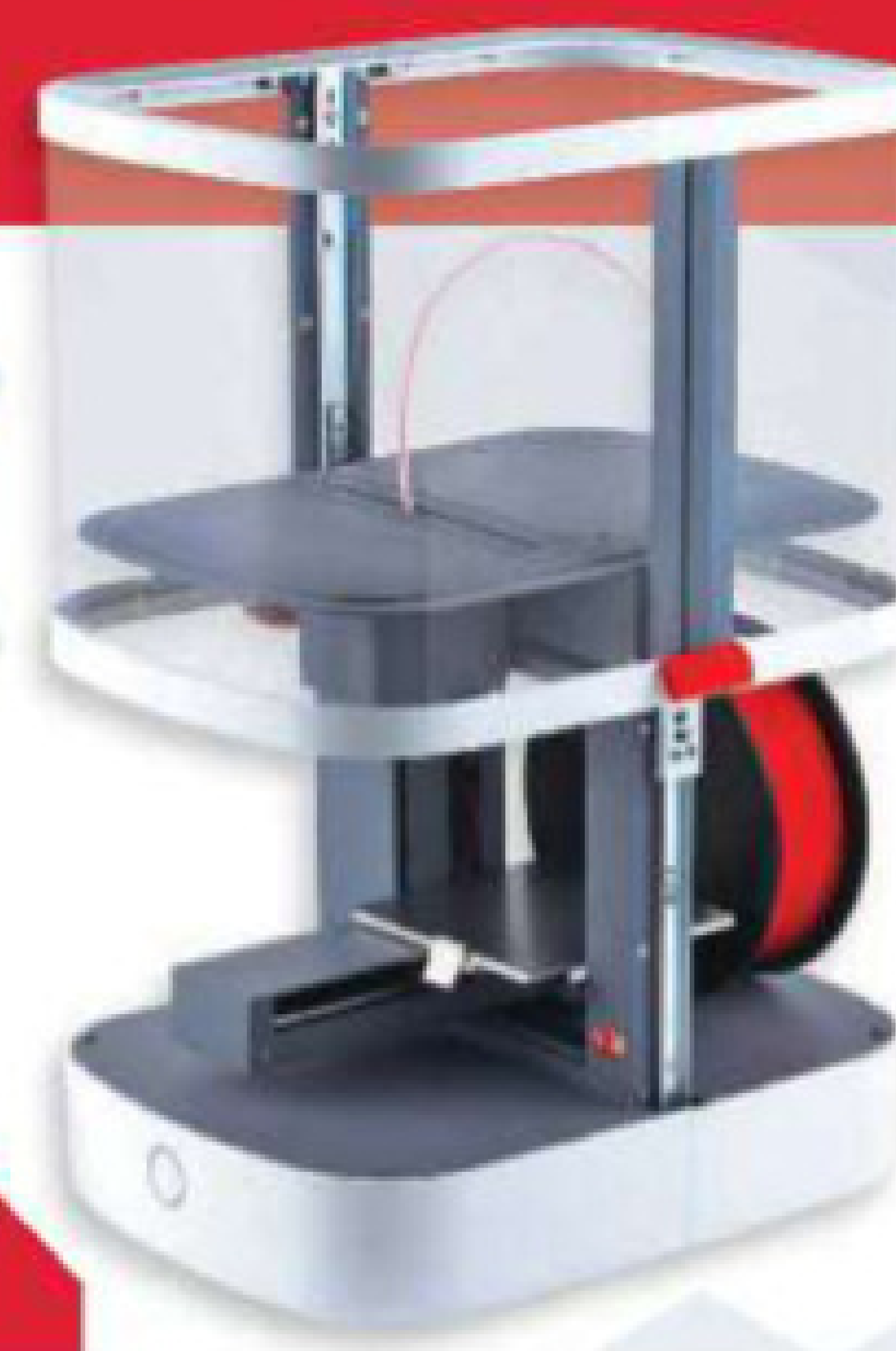
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Hard times for polar bears as pollution linked to penis bone

FIRST climate change, now penile fracture - polar bears have got it pretty rough. Chemical pollutants may be reducing the density of the bears' penis bones, putting them at risk of breaking this most sensitive part of their anatomy. Various mammals, though not humans, have a penis bone or baculum. Its exact function is unclear: it could just be a by-product of evolution, but some think it may help support the penis or stimulate the female during mating.

Christian Sonne at Aarhus University, Denmark, and colleagues examined baculum specimens from 279 polar

bears born between 1990 and 2000 in Greenland and Canada. They found that regions with higher recorded levels of polychlorinated biphenyls (PCBs) were associated with bears having a less dense baculum, which may prevent successful mating. "If it breaks, you probably won't have a bear which can copulate," Sonne says (*Environmental Research*, doi.org/zpj). His team has also shown that bears with high levels of similar pollutants in their bodies have smaller testes and penis bones.

PCBs were used in hundreds of applications, such as production of paints and rubber products, starting from the late 1920s - before we knew they were harmful. They were widely banned by 2001 but are slow to break down, so PCBs can accumulate in the environment. The Arctic has particularly high concentrations of these pollutants.

Star's golden song has a fractal theme

A PULSATING star's song could be the result of fractals at play.

Pressure changes inside a star can shuffle between layers of gas. Observers see the star appearing to "breathe" as its brightness fluctuates. The star's oscillations form a sort of melody with harmonies on top: our sun has a simple tune, variable stars a complex one.

William Ditto and his

colleagues at the University of Hawaii, Manoa, compared the two strongest tones made by the variable star KIC 5520878, using observations by NASA's Kepler space telescope. They noticed that the frequency of the secondary note divided by the primary, or lowest, note gives a value near the "golden ratio" - a number that shows up often in art and nature and is close to 1.618.

They then realised that its frequencies exhibited a fractal pattern: separating the tune into its constituent parts yielded more frequencies at weaker strengths, similar to the way coastlines retain their complexity as you zoom in. Three other pulsing stars with "golden" ratios also showed fractal patterns, while two non-golden stars did not (arxiv.org/abs/1501.01747). This could mean the golden songs could reveal insights into stellar physics.

Brain zapping results fizzle out

BRING on the second drenching. Researchers who threw cold water over brain stimulation science last year have done it again.

In November, they found that transcranial direct current stimulation (tDCS) - applying current to the brain to alter neuronal firing - has no consistent physical effect. Now it seems the same may apply to its effect on the brain's information processing.

Jared Horvath at the University of Melbourne in Australia pooled data from more than 400 studies reporting changes in cognitive skills following a session of tDCS. All showed positive results, such as accuracy on a memory task, but when combined, the results cancelled each other out.

"This is still a young field of research. The real results will come when we have enough data," says Roi Cohen Kadosh at the University of Oxford (*Brain Stimulation*, doi.org/zmg).

Lost your appetite? Umami tea can help

KELP tea, anyone? MSG-laden foods could help elderly people regain their appetite.

Five years ago, Takashi Sasano at Tohoku University in Sendai, Japan, found that some elderly people become less able to taste umami, while their ability to taste sweet, sour, bitter and salt remained intact. This coincided with a loss of appetite and weight loss, possibly because, of all the flavours, umami stimulates the most salivation, which in turn whets appetite. Now, Sasano has shown that MSG-rich kelp tea - which gives a huge umami kick - boosts elderly people's umami taste, along with their appetite.

MSG gets a bad rep, but the evidence that it is harmful is scant (*Flavour*, doi.org/zpg).

Drug buys time for nuclear survivors

KABOOM, nuclear meltdown. Exposure to DNA-damaging fallout happens in minutes, but getting treatment to combat the effects may take days. A new drug could help: in mice, it reduced death rates from radiation sickness even if given three days after exposure.

After a radiation hit, cells that are too damaged to repair themselves self-destruct, says Gábor Tigyi at the University of Tennessee. This leads to death if enough are affected. A naturally occurring molecule called lysophosphatidic acid (LPA) seems to give cells a better chance of survival.

In 2007, Tigyi and his colleagues developed a drug that interacts with LPA receptors on cells to reduce the effects of radiation sickness, but it wasn't potent enough to be useful. Now they have used a computer model to tweak the drug's structure to make a more powerful version, called DBIBB.

When mice were given DBIBB 26 hours after exposure to high levels of radiation, 13 of 14 animals were still alive two weeks later. Without the drug, 12 of 14 died. But prompt treatment isn't always possible, so Tigyi also ran tests to see what would happen if they didn't give mice DBIBB until 72 hours after exposure. One month later, 14 of the 15 mice were alive (*Chemistry & Biology*, doi.org/znj).



Solo supernovas cast doubt on cosmic distance standards

SOME supernovas might run a short fuse. These exploding white dwarf stars were all thought to detonate at the same size and with the same energy, thanks to a nudge from a companion star. But new research suggests some of them may go solo.

Type Ia supernovas go off so regularly because they are thought to be runaway thermonuclear reactions, in which carbon atoms inside white dwarf stars fuse together and release enough energy to blow the dwarf apart. To be dense

enough to start this kind of reaction, the white dwarfs need a mass 1.4 times that of the sun. If that's the case, then all type Ia supernovas have the same brightness. This makes them useful as "standard candles" to calculate cosmic distances and the effect of dark energy.

But white dwarfs don't grow that big on their own. To reach the threshold, astronomers thought they either steal mass from or crash into their neighbours.

Now Marina Orio at the University of Wisconsin-Madison

and colleagues suggest some white dwarfs are trigger happy. Lighter elements like hydrogen and helium can cause a runaway explosion at a lower density than carbon alone. They calculate that a "contaminated" white dwarf could go supernova at just 0.85 solar masses, even without a companion (arxiv.org/abs/1409.1104).

The findings could mean that up to half of supernovas are 30 per cent closer than believed. It could also mean dark energy is more powerful than we thought.

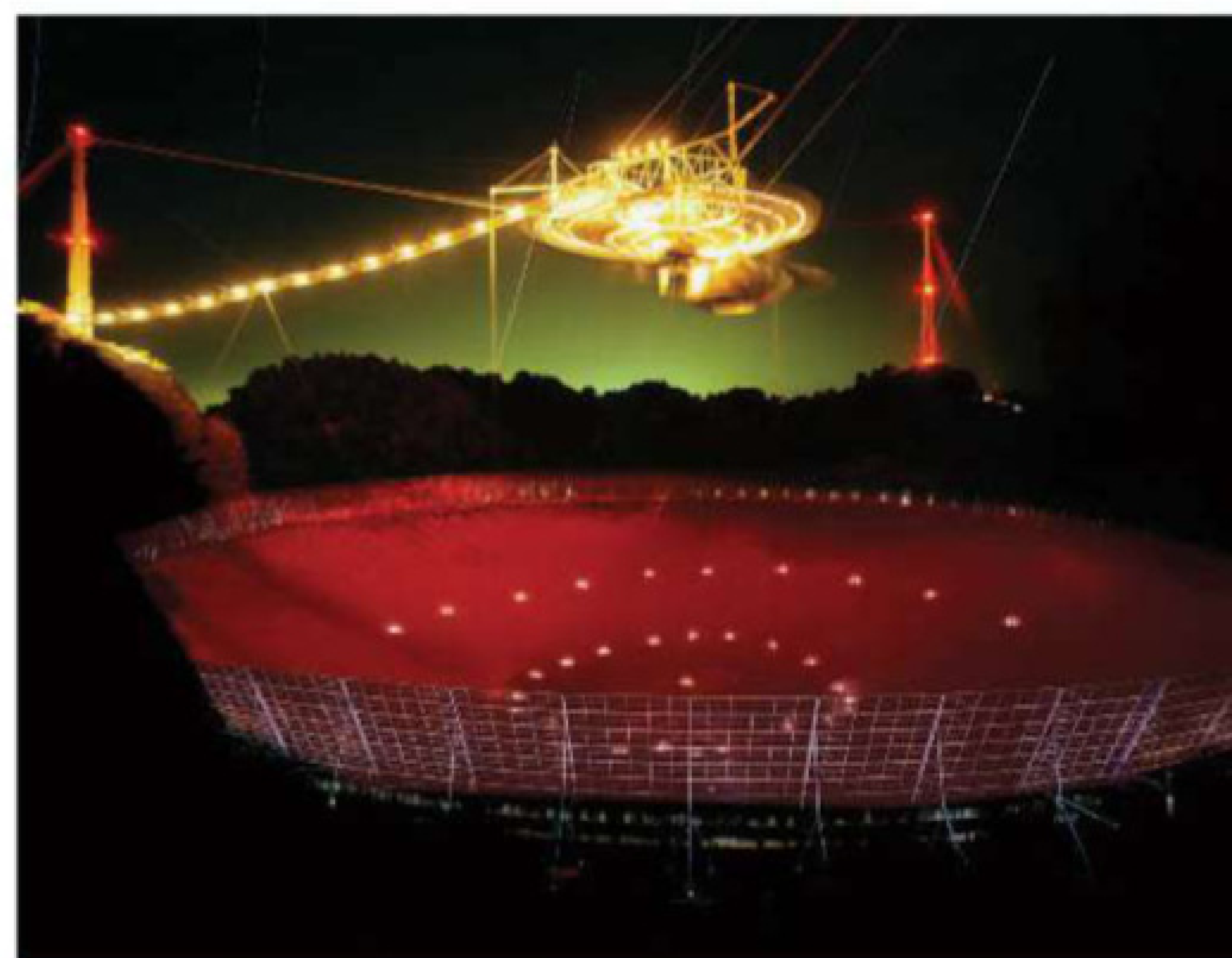
Climate change's double whammy

TALK about a left-right jab. One of the world's biggest sources of climate variability is set to develop a devastating double hit.

The El Niño Southern Oscillation is a natural fluctuation of ocean temperatures in the equatorial Pacific, whose extremes, El Niño and La Niña, drive droughts and floods from South East Asia to the Americas. When they are strong, the impacts are devastating. The 1997 El Niño, for example, is estimated to have killed 23,000 people and caused \$45 billion in damage.

Climate change is predicted to double the frequency of such El Niños this century. Now it seems extreme La Niñas will also start happening once every 13 years instead of 23 years, says Wenju Cai at the CSIRO in Melbourne, Australia, whose team ran 21 climate models with data for future carbon emissions (*Nature*, doi.org/zph).

The uneven warming of the Pacific Ocean is setting up a kind of see-saw, says Cai. "That means that the system swings between two extreme opposites." These can multiply the impacts of each event, with farmers being hit by droughts and then by floods.



To find ET, think broadband

THE hunt for alien civilisations may need an overhaul. It seems the signals we're listening for might not be the ones ET would choose.

Historically, SETI - the search for extraterrestrial intelligence - involves scanning the sky for radio signals sent by another civilisation. The simplest would be a constant blast in all directions, in a narrow range of frequencies.

But David Messerschmitt at the University of California, Berkeley, points out that a continuous signal would take a tremendous amount of energy. Assuming aliens have utility

bills, he says, they would opt for a different strategy.

Instead of a constant, narrow-band signal, Messerschmitt argues that ET would beep out short bursts in a wider range of frequencies - a broadband signal (*Acta Astronautica*, doi.org/znp). This would make it easier for ET to send a message, too.

That doesn't mean we should abandon the current approach to SETI, he says, but we could expand it to look for this alternative signal.

"I would not advocate putting all our eggs in one basket," he says. "We really don't know what ET is up to."

Internet's final frontier

Start-up firms and established players alike are looking to build fleets of satellites that will deliver high-speed internet from orbit

Hal Hodson

THE race is on to build a new kind of internet. A host of companies and billions of dollars are in play, with the ultimate goal of ringing the planet with satellites that will allow anyone, anywhere, to get online at broadband speeds.

Presently, satellite internet relies on spacecraft that are in geosynchronous orbit, travelling at the same speed as Earth rotates. But while this ensures the satellites are always in the same spot above Earth, it means there is a large time lag in the service, as radio waves take a quarter of a second to make the round trip up to a geosynchronous satellite and back. Added to the time for the other trips your data must take across the rest of the internet, the lag becomes unworkable for real-time applications like video or voice chat (see diagram, right).

To speed up the service, firms are looking at using satellites closer to Earth. This month, Virgin Galactic and chip-maker Qualcomm

announced their backing of a venture called OneWeb. This plans to put 648 satellites in orbit about 1200 kilometres above Earth's surface, where the round trip time for radio waves is just a few thousandths of a second, fine for any online application. SpaceX

"Satellites in orbit close to Earth could deliver high-speed internet to under-served areas"

immediately announced its own plan to do the same, building and launching 4000 satellites to a similar altitude. That would more than double the number of satellites in orbit.

The race has attracted more than just newcomers. Iridium Communications, based in Virginia, has provided satellite telephone services and low-bandwidth internet since the late 1990s. Its existing network of 66 satellites is set to be replaced by a new one called Iridium NEXT. Due to start launching this year,

the new satellites will be capable of delivering high-speed internet on a par with what OneWeb and SpaceX envisage.

And O3b, a sister company to OneWeb, already has 12 satellites at an altitude of 8000 kilometres. The firm provides connectivity to Colombia, the Democratic Republic of the Congo, South Sudan and Papua New Guinea.

Even internet giant Google has got in on the rush to space, investing \$1 billion in SpaceX's venture. The move is motivated by net neutrality concerns, says Kerri Cahoy, an aerospace engineer at the Massachusetts Institute of Technology. If the internet service providers that rule the physical infrastructure of the internet start charging web services to deliver content to users, the thinking goes, an alternative route to customers via satellites will be invaluable.

It's not the only reason. "It's a very interesting combination of motivations," says Cahoy. "Some of these guys are fuelled by ads.



The more eyes they reach and more products they convince people to buy, the more business. There's motivation to get commerce to everyone, even in underserved remote areas."

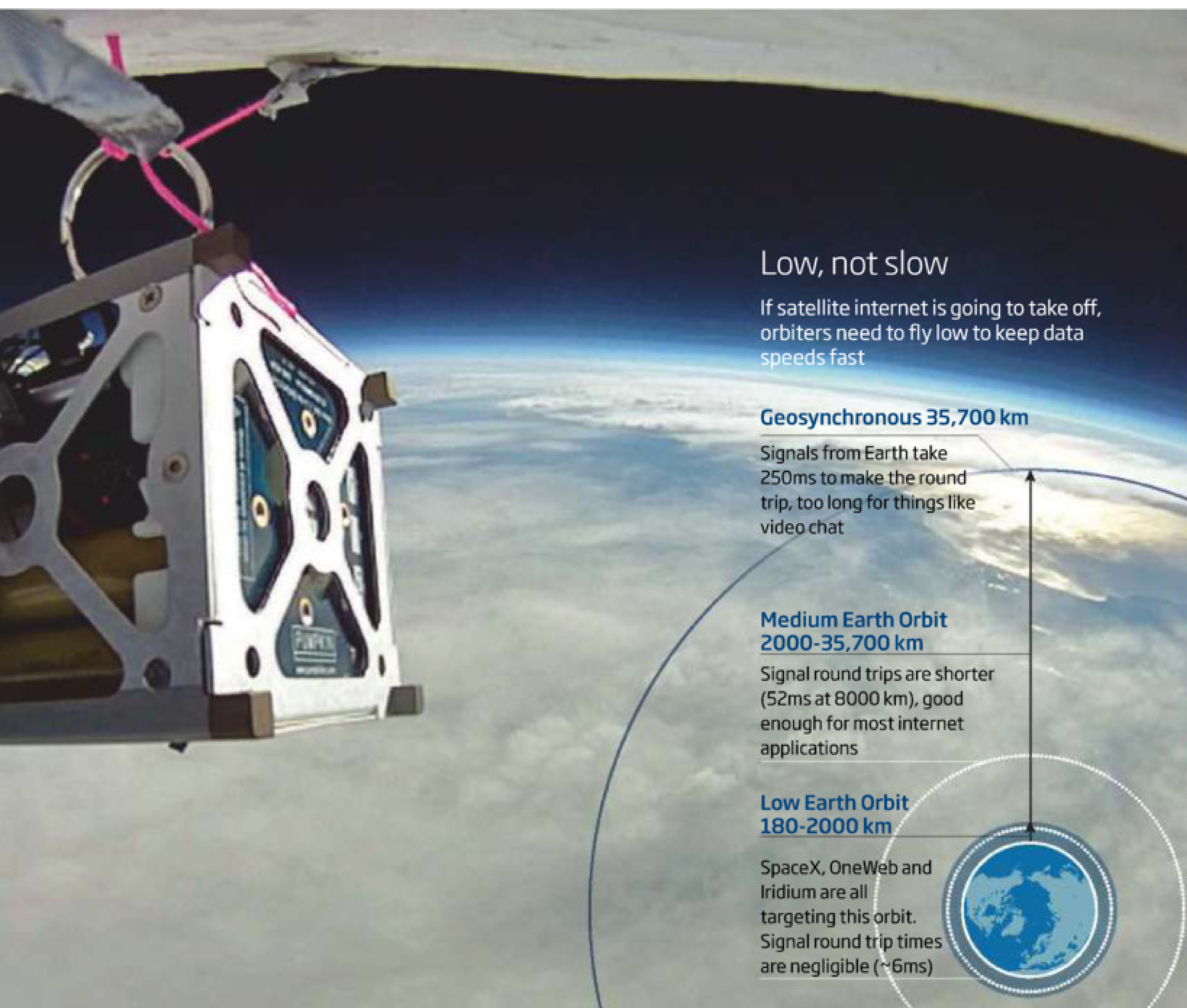
Will the space around Earth become crowded with all these satellites vying to route our data? "Space is big," says Cahoy. "I'm not worried about the physical interaction of the satellites as much as what they're using for the transmission. If they're using radio waves, those beams will have areas of overlap and interference."

Beaming down

Radio transmission is the most common way to communicate between satellites and Earth. However, as anyone who has had trouble with their wireless router knows, working with radio waves

SPACE RACERS

Company:	Iridium (Iridium NEXT)	O3b	OneWeb	SpaceX
Number of satellites:	66	12; >100 planned	648 planned	4000 planned
Altitude:	780 kilometres	8000 km	1200 km	1100 km
Weight:	860 kilograms	700 kg	~110 kg	100-500 kg
Internet bandwidth:	1.5 megabits per second (per customer)	160 gigabits per second (per satellite)	8 Gbps (per satellite)	unannounced
Positive:	Has been running a satellite network for decades	Is already providing internet connectivity to several countries	Founded by Greg Wyler, who also founded O3b	Company launches stuff into space as its day job
Negative:	Company's heritage and older technology may hold it back	Higher orbit means slower connections	Is planning to use Virgin Galactic's LauncherOne, which hasn't carried a single thing to space	Is nothing more than an idea at this stage



Low, not slow

If satellite internet is going to take off, orbiters need to fly low to keep data speeds fast

Geosynchronous 35,700 km

Signals from Earth take 250ms to make the round trip, too long for things like video chat

Medium Earth Orbit 2000-35,700 km

Signal round trips are shorter (52ms at 8000 km), good enough for most internet applications

Low Earth Orbit 180-2000 km

SpaceX, OneWeb and Iridium are all targeting this orbit. Signal round trip times are negligible (~6ms)

is finicky. So Cahoy and colleagues are working on using light to transfer data instead.

Easier to focus and send over long distances, laser signals could make it possible to build smaller, lower powered satellites that can still talk to the ground easily. "Radio has been the de facto," says Cahoy, "but there are links in the infrastructure that could easily be optical."

Miniaturisation and large drops in the cost of satellite components are boosting the push to space, says James Cutler at the University of Michigan. These have combined to increase access to orbit as never before. "I've got students that will leave with a master's and have built and launched five or six spacecraft," says Cutler. "That's never happened before."

Companies like O3b and SpaceX are planning to launch internet

satellites with masses of hundreds of kilograms, but Cutler says those of the future could be closer to 5 or 10 kilograms. Antenna weight can be brought down by using antennas that unfurl themselves in space, like those being developed by Sergio Pellegrino

"What you want to do is self-assemble a satellite in space, as this means you don't have to fight gravity"

at the California Institute of Technology. This means antennas of similar size to today's can be made of lighter materials as they will only have to support their own weight in microgravity, rather than on Earth's surface.

Cutler says satellite internet will really take off if companies make their equipment small enough to fit in Cubesats – small, lightweight

satellites that can piggyback on the launches of other vehicles. "That way every rocket that goes up is kicking off Cubesats," he says, with each small orbiter perhaps holding only a fraction of a functional communications rig.

"What you want to do is start to self-assemble," he says. Instead of building large satellites on Earth and then fighting gravity to get them in orbit, the components themselves would be launched, then come together in space to form a light, powerful satellite. A network of such orbiters should be able to provide coverage that is similar to the signals terrestrial cellular towers already pump out.

"It's a brand new space race in many ways," says Cutler. "But instead of being fuelled from a defence perspective, it's being fuelled by an internet perspective." ■

Big data aims to boost New York blood donations

CAN the right words convince someone to donate their blood? An initiative in New York has turned to machine learning to figure out who is most likely to give blood – and how to encourage them to do so more frequently.

The project is aimed at improving the turnout of African Americans, who are disproportionately less likely to donate or become regular donors. Though race is not relevant for standard blood transfusions, type B blood is more common in African American people. Also, ethnicity may help provide a match for blood transfusions to people with sickle cell disease, a condition that is seen more often in African Americans.

"Minorities provide blood that's needed for specific patient populations," says Beth Shaz, chief medical officer at the New York Blood Center. "With the development of this tool, we can create messages tailored for that individual."

To find out who to reach out to, the blood centre teamed up with Hindsait, an AI start-up in Englewood, New Jersey. Hindsait combed through more than a million donation records from the last 10 years to develop an algorithm that could identify telltale signs that someone might return to donate again. Criteria such as the number of days since their last donation, whether or not they were eligible to donate at the time, and their age were taken into account.

Starting on 1 February, the blood centre will use this data to choose who to contact and what to say – a strategy reminiscent of Barack Obama's 2012 presidential campaign, which sent different emails to prospective funders based on their age and gender. For example, younger people might receive text messages rather than emails. Messages to African Americans will emphasise the particular importance of blood donation for their community. Aviva Rutkin ■

How to avoid buried treasure when you dig

IN 2010, when builders were excavating the site of the former World Trade Center in New York, they stumbled across something rather unusual: a large wooden boat, later dated to the 1700s.

Hitting archaeological remains is a familiar problem for builders, because the land they are excavating has often been in use for hundreds, if not thousands, of years.

Democrata, a UK data analytics start-up, wants to help companies guess what's in the ground before they start digging. Using predictive algorithms, their new program maps where artefacts might still be found in England and Wales, in order to help companies avoid the time and cost of excavation. "It's an expensive problem to have once you've started digging," says Geoff Roberts, CEO of Democrata.

Archaeological services can amount to between 1 and 3 per cent of contractors' total construction cost. "We wanted to bring data science in as an added tool, so humans involved in the process could use it to understand what would likely be found," says Roberts.

The Democrata team scoured documents from government departments such as the Forestry Commission, English Heritage and Land Registry to find out what the land was used for in the past, for

example, and about known archaeological sites. This included "gray literature", the massive set of unpublished reports written by contractors every year.

With the aid of a supercomputer, they developed models that can pinpoint where treasures are likely to be hidden underground. For instance, land close to water, tin mines or sites of religious significance was ranked more highly than land elsewhere. Other factors like the

"Archaeological services are generally between 1 and 3 per cent of the total construction cost"

local geology, animal and plant life also contributed to the score.

This week, Democrata will present the program to engineering companies and the government to hear their feedback.

Henry Chapman at the University of Birmingham, UK, says the tool may impede new discoveries in archaeology. "If you think about the number of archaeological fieldwork excavations that take place purely for trying to find out about the past, that's a very small amount compared to all of the excavations done before commercial development," he says.

Aviva Rutkin ■



Looks like we missed the boat

ONE PER CENT



Robo-jazz band gets freestyling

Dig those robot grooves. Mason Bretan at the Georgia Institute of Technology in Atlanta has released a video showing him playing a jazz song with four robot musicians. Two bots play composed percussion while a third creates an original tune, although they play music through speakers rather than wielding instruments. But the fourth robot, a larger four-armed bot called Shimon, pictured, improvises on the marimba, showcasing its ability to get into the right position to hit the right notes. Watch them at bit.ly/robojazz.

"A gravitational-wave detector Help us control it with our mind Don't, unless advised by a doctor Comes in two forms, scientists find"

The first four lines from an auto-generated poem based on tweets from *New Scientist's* account, courtesy of new website **Poetweet**. Add any Twitter handle, pick one of three poetry forms, and the site does the rest

Create a video game to learn

Playing with your phone in class could soon be compulsory. A pilot project involving 600 pupils aged 8 to 17 in five schools in the UK, Austria and Spain will investigate how making video games could help kids learn. Students will use a smartphone app called Pocket Code to write mobile games exploring curriculum subjects, such as making a case for the abolition of the slave trade in the 1770s.

Scarves do more than keep you warm

Smart scarves are the next big thing. Well, OK, they're probably not, but a fun prototype called SWARM, designed by Microsoft researchers, can heat up, vibrate or play music and is controlled by a smartphone app. It can also link to a heart monitor sensor to react to changes in your mood. Another smart scarf, Scarfy, triggers different apps on your phone depending on the way you tie it and can scrunch up by itself to signify an incoming phone notification.

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Watch out, it's a poonado!

ENCOUNTERING a mighty sperm whale is a magical experience. But in this case, it was tempered somewhat by a rarely seen defence mechanism: emergency defecation.

Sperm whales are the largest toothed predators in the world, so what have they got to be scared of? Here it was pesky divers buzzing around them, taking photos.

Canadian photographer Keri Wilk was sailing off the island of Dominica in the Caribbean, hoping to film these gargantuan creatures, when he spotted one and jumped in for some close-ups. The whale approached Wilk and his three colleagues, pointed downwards, and began to evacuate its bowels. To make matters worse, it then started to churn up the water. "Like a bus-sized blender, it very quickly and effectively dispersed its faecal matter into a cloud," says Wilk.

Defensive defecation has been recorded in pygmy and dwarf sperm whales, which, as their names suggest, are diminutive compared with their cousins. But this is perhaps less surprising, given that they have natural predators. Wilk is unaware of any other reports of sperm whales' emergency excretion.

Despite what you might think of being enveloped in what Wilk describes as a "poonado", he cherishes the moment. "I've experienced lots of interesting natural phenomenon underwater, all over the world, but this is near the top of the list," he says. "As long as you didn't take your mask off, you couldn't really smell anything. Taste is another matter..." Rowan Hooper

Photographer

Keri Wilk

www.KeriWilk.com

Clearing the air

Obama wants to cut smog; Republicans cry foul over costs. Europe's limit looks tougher, but is it? **Fred Pearce** peers through the haze

"VOTE Republican: vote smogs". I doubt many bumper stickers carried that message during last year's US midterm elections. But choking air and kids dying of asthma may be what the Republican victory delivers.

Republicans now control both houses of Congress and are all for throttling President Barack Obama's plans to lower the federal limit on ozone smog, announced by the US Environmental Protection Agency (EPA) right after the elections. They say it is unachievable, except at vast cost.

This might surprise Europeans, who have been living with a tougher limit for some time. However, an analysis for *New Scientist* suggests that Europe's limits are less stringent than they appear. And reports from Brussels in recent weeks suggest that anything tougher is off the agenda because of concern about the impact on fragile economies.

Ozone in the stratosphere, miles above the ground, is a good thing, shielding us from cancer-causing ultraviolet radiation. But it is also a strong corrosive oxidant. At street level it triggers asthma attacks, damages children's lung development and causes heart problems in the elderly. It also cuts crop yields, slows tree growth and eats away at textiles – all at levels commonly found in industrialised nations.

The pollutant is unusual in that we don't emit much directly. It is largely a secondary product, created photochemically. Nitrogen oxides from burning fuel react in sunlight with volatile organic compounds from solvents



plus vehicle engines and oil refineries. This cocktail brews especially in summer, though it takes a few hours for the concentration of ozone to peak, so the highest levels are often found in suburbs or countryside downwind of urban areas, where pockets of pollution will have drifted in those few hours.

The health risks scale up with the duration of continuous exposure; regulators mostly measure 8-hour averages. Places breach limits when they have too many days with excessive amounts over 8-hour stretches.

The first US ozone standard was set in 1979, at 120 parts per billion. It was lowered in 1997 to 84 ppb

and again in 2008, under President Bush, to 75 ppb. Many major US cities such as Chicago, Dallas, Houston and much of California regularly breach the Bush limit.

But doctors say the limit should be lower still. The World Health Organization reports that healthy adults and children exposed to ozone at 60 ppb for several hours experience inflamed lungs and breathlessness. In 2005, the WHO recommended a limit of 50 ppb.

Regulators have been timid. The

"The air at Sevenoaks, near London, passed Europe's ozone test easily but could fail the proposed US limit"

Obama administration initially vetoed a tougher stance. But last November, the EPA finally proposed a new limit of between 65 and 70 ppb. It would come into force between 2020 and 2037, with problem cities getting most time to adjust. "Bringing ozone pollution standards in line with the latest science will clean up our air [and] protect those most at risk," said EPA administrator Gina McCarthy. But 2037 is a long time to wait if you have asthma.

Opponents say meeting such a limit will require expensive retrofitting of scrubbers to remove nitrogen oxides from power plant fumes, and either new technology for vehicle exhausts or limits on transport. It "could cost up to \$270 billion a year and place millions of jobs at risk", according to the US National Association of Manufacturers. The EPA dismisses that, reckoning that a 65 ppb limit would cost \$15 billion a year in return for health benefits worth twice as much: annually, up to 4300 fewer premature deaths, as many as 960,000 fewer childhood asthma attacks, and a million fewer missed schooldays.

In the dog days of his administration, Obama is keen to use his executive powers to bring on environmental measures of this sort. But Congress is not in a mood to lie down. Both the Senate and House of Representatives are looking at Republican proposals requiring the EPA to consider the impact of air-quality rules on jobs, something it is not allowed to do at present. Republicans may also take aim at EPA funding. Smog

sceptics, like climate sceptics, seem to have subjugated environmental concerns to their narrow political agenda.

All this makes Europe look good. A European Union ozone limit of 60 ppb – deemed unattainable in the US – has been in force since 2010. But US and European limits are not directly comparable, and here's why.

In the US, being in breach of the regulations means exceeding the limit on four or more days in a year, averaged over three years. So 11 breaches in any three-year period is fine, but 12 is not. In Europe, the limit can be exceeded up to 25 days a year, again averaged over three years. So up to 75 bad-air days are allowed in that time. That's a lot, but even so large parts of southern Europe failed that test for the period 2011 to 2013, because of a spike during the hot summer of 2013.

So which policy is tougher? I asked smog scientists at King's College London to compare them. Gary Fuller and Tim Baker looked at 17 years of data, from 1998 to 2014, at Sevenoaks, just outside London. The results are remarkable. They found that Sevenoaks air passed the EU test easily, never getting close to the 75 bad-air-days limit in any three-year period. But it exceeded the proposed US test in no fewer than 12 three-year periods. "For south-east England, the [proposed] US EPA limit is more stringent than the EU one," says Fuller.

This should not give succour to critics of the EPA proposal. The medical evidence shows it is urgently needed. The shock is that the apparently stringent EU limits are, in reality, so lax. They need toughening. Which makes recent reports that EU environment ministers are trying to stymie initiatives to do that as distressing as Republican denialism.

Smogs? Kids' health? Who cares any more? ■

Fred Pearce is a consultant for *New Scientist*

QUEEN ELIZABETH PRIZE FOR ENGINEERING

Make things better

The Queen's prize recognises the huge contribution engineers make to our everyday lives, says **The Duke of Edinburgh**



PROFILE

Prince Philip is the husband of Queen Elizabeth II and Senior Fellow of the Royal Academy of Engineering. In 1957, he wrote to *The New Scientist* to congratulate it on its first anniversary and wish it many more

IF YOU look around you, everything you see that isn't part of the natural world was the vision of an engineer or an architect. Every power station, every road, every railway, every bridge, every mobile phone, every airliner, every piece of equipment and every sewage works owes its existence to an engineer.

Great engineers have a passion to improve life; a burning conviction that they can make life better for everyone. Engineers need to have a talent for invention and innovation, but what drives them is the conviction that they can find a better way to do things; a cheaper and more efficient solution to the problems of human existence on this planet of limited resources that we call Earth.

Many of us spend a lot of time complaining about the difficulties and problems of life. It is easy to find fault with things that make daily life arduous. For an engineer, these difficulties can be opportunities. How can this be made to work better? How can that process be made more efficient? How can components be made more cheaply, more accurately and more fit-for-purpose? Great engineers are

convinced that everything can be improved. Instead of complaining, they think of ways to make things better.

In addition to ambition, those who aspire to change the world for the better also need to acquire the skills and knowledge that previous generations have bequeathed to the art and science of engineering.

Many people take to engineering because they discover that they already have technical skills; they can make things with great precision. Others discover that they can put ideas on paper or computer screens. This is frequently all it takes to start them thinking about how they can use these talents to do something original, or to devise a way of doing something better. They may have to go through years of struggle and disappointment, but this seldom diverts them from their vision and ambition to innovate.

Engineering is not just a profession to be learned and practised as a way of making a living. It is one of the few ways in which human talent can be given the chance to improve, and frequently to transform, the comfort and prosperity of the human community. In fact, engineering has made a greater positive difference to human life than almost any other human endeavour.

The Queen Elizabeth Prize for Engineering is intended to recognise those particular feats of engineering that have made a significant impact on human existence. The winners are an example of what can be achieved, but it must not be forgotten that they were supported and enabled by countless other specialist engineers, from this time and throughout the past.

It is obviously not possible to name every one of them, but they will all appreciate that they have played their parts, and that, I hope, will give them the satisfaction of knowing that they have created a very significant contribution to the human lot. ■

The winner of the 2015 Queen Elizabeth Prize for Engineering will be announced on 3 February. You will be able to read an interview with them on newscientist.com

Seduced by the beauty of mathematics

Do we have an inbuilt maths drive, a bit like a sex drive, asks mathematician **Manya Raman Sundström**

MATHEMATICIANS are famous for the lengths they go to when solving problems. To crack Fermat's Last Theorem, Andrew Wiles worked in isolation for more than six years. And Thomas Hales produced a body of work consisting of 250 pages of notes and 3 gigabytes of computer programs to solve Kepler's Conjecture, a problem open since 1611 regarding the most efficient way to stack cannonballs.

What is it that motivates mathematicians to go to these extremes? It seems there is something compelling, almost seductive, about their subject. Could there be some sort of drive, similar to the sex drive? In other words, something that we could call a "maths drive" that urges us to find new mathematical explanations and truths?

As strange as this idea sounds, it is not without precedent. In 2000, the psychologist Alison Gopnik suggested, in full seriousness, that finding an explanation is like having an orgasm. Similarly, the physicist Robert Oppenheimer, a father of the atomic bomb, claimed that "understanding is a lot like sex. It's got a practical purpose, but that's not why people do it normally."

Can intellectual pursuit be as compelling as bodily urges? It might be going too far to claim that the drive to do mathematics has evolutionary roots, but perhaps not too far to suggest that it could be as rooted as the desire to reproduce – and that the production of meaningful, significant mathematics might be just as satisfying as sex.

At the core of this hypothesis is a claim that doing mathematics is, at least in part,

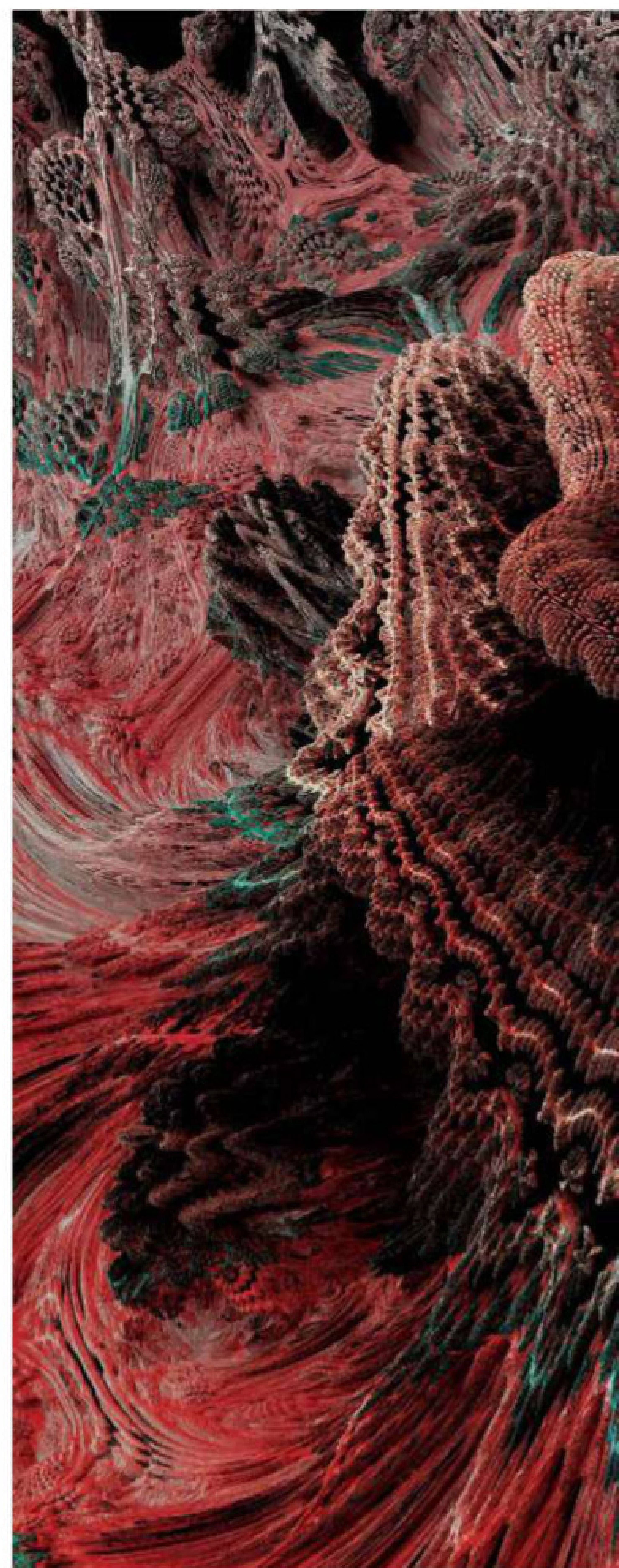
aesthetic. It is a human trait to hunt for what is beautiful, and we do so because beauty is compelling. I contend that the same is true of mathematics. Beauty – or aesthetics more generally – is not just a by-product of the subject. It isn't that you look back at the end of day and notice that a proof or definition is beautiful. It seems to be that beauty is an essential part of the process. In her article "The role of the

"Can intellectual pursuit be as compelling as bodily urges?"

aesthetic in mathematical inquiry", Nathalie Sinclair of Simon Fraser University, in Canada, finds that aesthetic sensibilities help guide the mind and maintain interest in a problem, as well as influencing the choice of problems to work on and the quest to find solutions to them.

This is not to say that all mathematical work is beautiful. Some proofs are tedious and long. Some, like Hales's proof of Kepler's conjecture, require computer code and are difficult to check. And it is not clear that aesthetic experiences are uniform. What is beautiful to a geometrician might not be to an algebraist. What was beautiful to you as a graduate student might not be after 20 years of research.

Although research on the nature of mathematical beauty is under way in several fields – such as philosophy, psychology and education – there are



still many open questions. What do we mean by beauty? Is it objective or subjective? Can equations be beautiful in their own right, or must they be connected to some sort of visual or sensory representation? And how does the feeling of beauty manifest itself in the brain?

Answers are beginning to emerge. For example, a recent study led by Semir Zeki at University College London involved scanning the brains of mathematicians



while they viewed different formulae, such as Euler's identity, $e^{i\pi} + 1 = 0$, an equation rated as beautiful by the participants. The scans showed that the experience of mathematical beauty excited the same area of the brain as music or art (*Frontiers in Human Neuroscience*, vol 8, p 68).

My research has shown that there is some consensus about what kinds of mathematical proofs are deemed beautiful (*Research in Mathematical*

Art can be made from equations, but equations can be works of art in themselves

Education, vol 15, p 199). Those found to be beautiful seem to give a more immediate sense of why the claim is true. For instance, a geometric proof of the relationship between the sides of a right-angled triangle, that compared areas of small triangles inside it, was considered more aesthetically pleasing than an algebraic proof. This is probably

PROFILE

Manya Raman Sundström is in the Department of Science and Mathematics Education at Umeå University, Sweden. She investigates the teaching and learning of mathematical proofs, as well as mathematical aesthetics. She blogs at mathbeauty.wordpress.com

because the algebraic proof gives no immediate sense of why the theorem is true.

Whatever we mean by the term “mathematical beauty” and how we judge it, there is no doubt that aesthetics plays a significant role in the working life of mathematicians. Last year, after she won the Fields Medal, the maths world's Nobel prize, Maryam Mirzakhani talked about “the beauty of math” that one can appreciate after a lot of hard work. But how many children work through their years of schooling without experiencing this kind of appreciation? If there really is a “maths drive”, at least in some proportion of the population, do we do enough to tap it?

It is not obvious whether the beauty of mathematics can be conveyed at the school level, but this question is not one that has received a great deal of attention. School lessons tend to be centred on a standard set of mathematical topics and processes. There has been little discussion of aesthetics, despite its motivational capacity. A leading journal, *Educational Studies in Mathematics*, called mathematical aesthetics one of the most under-researched areas in the field.

The question for school mathematics is simply this: do we teach it without conveying the true nature of the subject? Teaching maths solely in terms of procedures such as practising sums is like teaching music through practising scales without ever exposing children to Beethoven.

When experiencing a moment of true mathematical understanding – grasping why something is so, or seeing how everything hangs together – you can feel a sense of meaningfulness, connection and purposefulness, just as you might with poetry or music. Perhaps this was what the prolific mathematician Paul Erdős meant when he claimed that certain proofs were so perfect they were divine.

Once you realise that mathematics is, in addition to its scientific merits, an essentially aesthetic subject, you realise that teaching it to students without conveying its beauty might be to miss the essence, the very life, of the subject. ■

LAGUNA DESIGN/GETTY

DAWN of the PLASTICENE

ONE million years from now, geologists exploring our planet's concrete-coated crust will uncover strange signs of civilisations past. "Look at this," one will exclaim, cracking open a rock to reveal a thin black disc covered in tiny ridges. "It's a fossil from the Plasticene."

Our addiction to plastics, combined with a reticence to recycle, means the stuff is already leaving its mark on our planet's geology. Of the 300 million tonnes of plastics produced annually, about a third is chucked away soon after use. Much is buried in landfill where it will probably remain, but a huge amount ends up in the oceans. "All the plastics that have ever been made are already enough to wrap the whole world in plastic film," palaeobiologist Jan Zalasiewicz of the University of Leicester, UK, recently told a conference in Berlin, Germany. It sounds enough to asphyxiate the planet.

What will become of this debris? Landfill will stay buried until future generations rediscover it, but it's a different story for plastic that reaches the ocean. Some is washed up on beaches or eaten by wildlife. Most remains in the sea where it breaks down into small fragments. However, our knowledge of its ultimate fate is hazy. We don't really know how much plastic pollution is choking the seas. Nor do we understand its potential impact on the health of sea creatures and those who eat them. Nor do we have any idea where the stuff will end up in the distant future – will plastic debris break down entirely or will it leave a permanent mark?

The scale of our plastic problem became clear in 1997 when US oceanographer Charles

Pleistocene, Holocene...
what's next? Our love
for plastics is leaving
a lasting legacy,
says Christina Reed

Los
Angeles rivers
dump around **30** tonnes
of plastic
into the Pacific every day

Moore came across a huge area of floating trash – now dubbed the "Great Pacific Garbage Patch" – as he sailed across the Pacific Ocean from Hawaii to California. It was soon found that other oceans contained similar concentrations of rubbish.

These patches are created by surface currents, or gyres, which meander from coast to coast in circular loops on either side of the equator – clockwise in the northern hemisphere and anticlockwise in the southern hemisphere. And just as noodles gather in the centre of a bowl of stirred soup, anything caught in these currents is likely to drift into the middle. The five biggest concentrations of marine debris are in the Indian Ocean, the North and South Pacific and North and South Atlantic (see map, p 30). This year Moore reported finding one spot in the Pacific gyre where there was so much accumulated rubbish you could walk on it.

Most of the debris is plastic. "On a global basis, about 70 per cent of all the litter in the sea is plastic," says marine biologist Richard Thompson of Plymouth University, UK.

How much is that? To find out, an international team headed by Marcus Eriksen at the Five Gyres Institute in Santa Monica, California, gathered data on the amount of plastic caught in nets towed behind research ships on 24 expeditions over a period of six years. This was added to records from spotters who stood on the decks of these ships and counted every piece of plastic they observed. The team estimate that 5.25 trillion pieces of plastic, weighing more than 260,000 tonnes, are currently floating at sea. Most is big stuff like buckets, bottles, bags, disposable ➤



“FOR SOME MICROBES, WASTE PLASTIC IS THE EQUIVALENT OF A HOTEL BUFFET TABLE”

In 2013 China produced **24.8** per cent of the world's plastics. Europe produced **20** per cent

packaging and polystyrene foam. The highest concentrations found were on the order of 10 kilograms of plastic – equivalent to about 800 water bottles – per square kilometre. Given the huge size of the oceans, this represents an incredible amount of trash.

What is most surprising, however, is that Eriksen and his team didn't find more plastic. According to PlasticsEurope, a plastics industry trade association, production has increased from 1.5 million tonnes annually in the 1950s to 299 million tonnes in 2013. Given that it's often cheaper for manufacturers to produce virgin material than to buy and use recycled plastic, much of this material is thrown away after use. For example, in 2012, only 9 per cent of the 32 million tonnes of plastic waste generated in the US was recycled.

Eriksen's study found less than 0.1 per cent of the plastic produced each year. This is close to the result of a 1975 survey by the

US National Academy of Sciences, which estimated that 0.1 per cent of global plastic production makes its way into the ocean annually – equivalent to about 300,000 tonnes this year.

More surprisingly, the amount of plastic in the gyres doesn't seem to be changing. A team led by oceanographer Kara Lavender Law of the Sea Education Association in Woods Hole, Massachusetts, combed through decades of data recording plastic collected during research voyages in the North Atlantic and the Caribbean Sea, and found that the amount was fairly constant (*Science*, vol 329, p 1185). “Despite a strong increase in discarded plastic, no trend was observed in plastic marine debris in the 22-year data set,” they reported. “Where is all the plastic?” asks Law.

The answer could be that plastic breaks down more quickly than we thought, as the action of sunlight and waves degrades it into small fragments. The missing plastic may exist as a soup of tiny pieces suspended in the water column.

In July 2014, Andrés Cózar of the University of Cadiz in Spain, working with a team of international marine scientists, calculated the total amount of plastic fragments floating in the seas at between 7000 and 35,000 tonnes (*PNAS*, vol 111, p 10239). Eriksen's team reckons there are 35,500 tonnes of plastic particles measuring less than 5 millimetres across (*PLoS One*, e111913). But both figures seem low – a million tonnes of these tiny pieces should have been found in the water.

Through the net

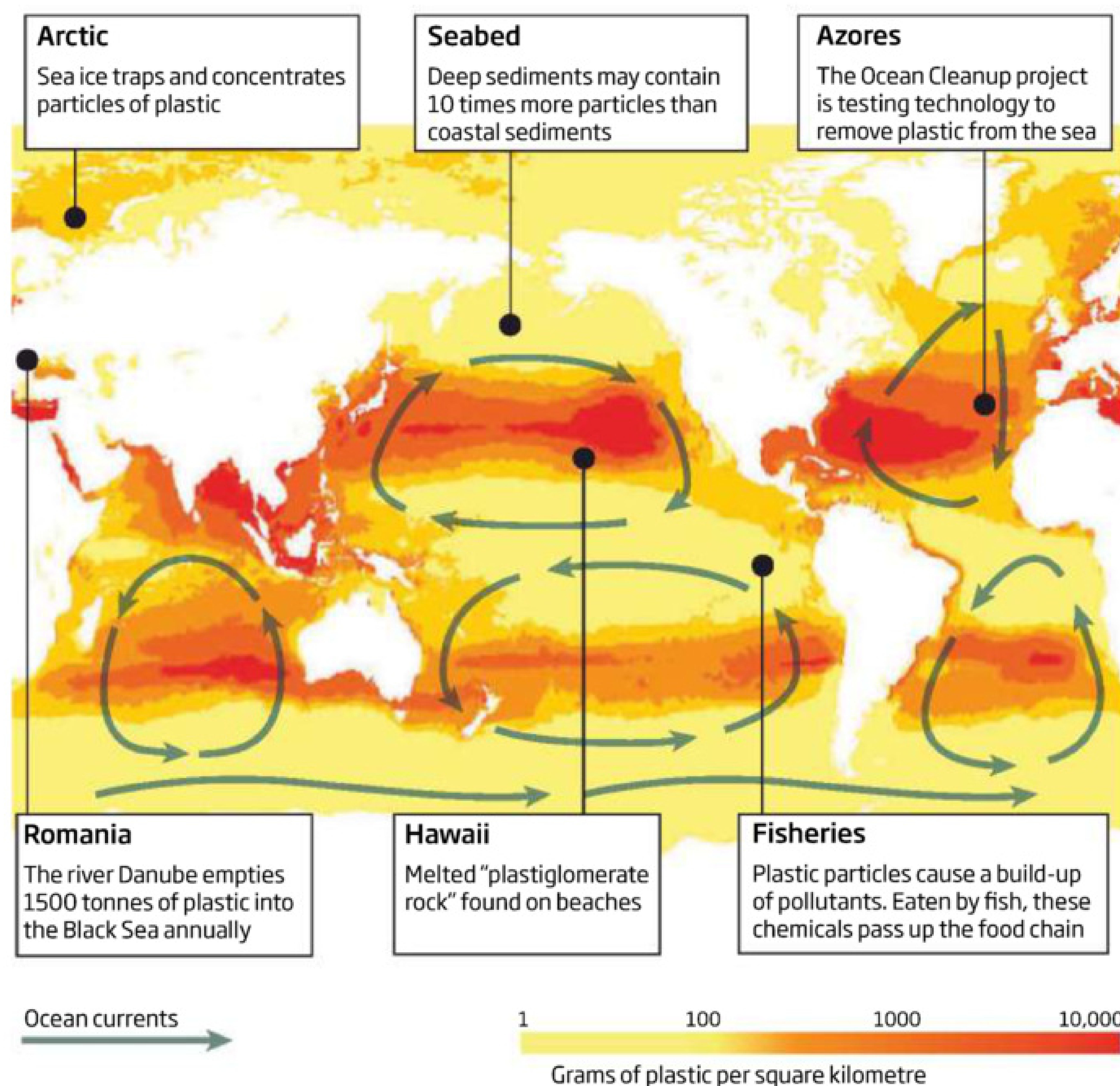
There are a few possible explanations. Plastic particles less than a third of a millimetre across will slip through the trawl nets because the mesh size is too large, so a huge amount of plastic could have been overlooked.

Thompson believes that some plastic might also be locked up in ice. In June 2014, his team reported finding up to 234 particles of plastic per cubic metre of Arctic sea ice – several orders of magnitude higher than in the heavily contaminated waters of the gyres. He suggests that as seawater turns to freshwater ice, it traps and concentrates small particles. Given that there are about 6 million square kilometres of sea ice, this could represent a huge reservoir of plastic. If the ice melts, this material will be released back into the sea.

More recently, Thompson's team has discovered another place where plastic is accumulating. In December, the group published data showing that tiny pieces of plastic and other polymers, mostly in the

Global garbage dump

Much of the ocean's plastic waste is found near heavily populated coastlines, but farther out, it is concentrated in five “gyres” in the Atlantic, Pacific and Indian oceans. Where most of it ends up is unclear





E. ZETTLER, SEA EDUCATION ASSOCIATION

Buoyed up: floating plastic offers shelter to sea life and can create oases in the ocean

form of fibres, are up to four times more abundant in deep-sea sediments in the Atlantic Ocean, the Mediterranean Sea and Indian Ocean than in surface waters. Samples contained up to 800,000 particles per cubic metre. The small number of samples – just 12 sediment cores taken from seven expeditions, and four coral samples – was small, but they found plastic debris everywhere they looked.

Could deep-sea sediments hold the key to the missing plastic? It seems likely, given that there are about 300 million square kilometres of seabed.

Some plastic particles are heavier than water and will sink, while others will become colonised by creatures such as phytoplankton, or clump together with other particles and drift downwards towards the seabed like falling snow. This process could be aided by ocean currents, Thompson says.

Confirming this model won't be easy. We don't know the density of minute particles of plastic in the sea, says Law, because we don't have a good way to measure anything there that is smaller than about 0.5 millimetres. But marine geochemist Tracy Mincer of the Woods Hole Oceanographic Institution has a solution. His group is using a special laser scanning microscope to investigate seawater. "We have just begun this work and are seeing plastics in the 2-20 micrometre range," he says.

There are similar gaps in our knowledge when it comes to understanding what impact this stuff is having on marine creatures. We know larger creatures like birds, turtles, fish

and whales confuse plastic trash with food, and then choke to death or die of starvation as their stomachs become clogged. But the effect on smaller sea dwellers is far more complex.

For some microbes, plastic is the equivalent of a hotel buffet table. Any hard surface in the ocean becomes a collection plate for nutrients, says Mincer. This is why structures like oil rigs or sunken ships become oases of life.

Other species, too, are taking advantage of the floating debris. Across the Great Pacific Garbage Patch, the insect species *Halobates sericeus*, a type of water strider, deposits its eggs on the floating plastic. As plastic debris has increased in the Pacific, so too has these insects' reliance on it.

H. sericeus isn't alone. Erik Zettler of the Sea Education Association, working with Mincer and Linda Amaral-Zettler of the Marine Biological Laboratory in Woods Hole, discovered that the plastics are even providing an entirely new ecosystem – one Amaral-

The river Danube releases

4.2 tonnes of plastic **per day** into the **Black Sea** or

1533 tonnes **per year**, which is **more than the estimated total amount of plastic in the North Atlantic gyre**

Eating shellfish

can expose you to **11,000** pieces of microplastic **every year**

Zettler dubs the "plastisphere". Like the rhizosphere of microbes colonising roots, there is an entire "cast of characters that colonise plastic", says Mincer. The ones that are attracting most of his attention are bacterial strains called *Vibrio*. "These are very good at colonising surfaces and can be pathogenic as well," he says. There have been cases of people getting a hook caught in the hand while fishing at sea and coming down with *Vibrio* infections that are difficult to treat, he says.

Pathogenic *Vibrio* colonise the intestines of fish, empty the tissues of nutrients and salts, and break down blood cells to collect iron. Once excreted, they can attach themselves to a piece of plastic, regroup and wait to attack the next fish that mistakes their home for plankton.

Viruses might also find plastic useful. "We can't say confidently 'that is a virus' but we do see viral signals in the metagenomic data sets from plastic," says Mincer. It's not surprising, he says: there are far higher concentrations of viruses in the water column than there are microbial cells. "The more I look at genomic sequences, the more I tell my team to wash their hands and be careful," he says.

There are other reasons to worry about plastics. There is evidence that plastic microparticles are entering the food chain. *Vibrio*, for example, are bioluminescent, and can create a spectacular blue-green glow in the water. "During midnight tows in the summer, you frequently see the plastic glowing in the dark," says Mincer. The fact that plastic particles loaded with harmful bacteria mimic food using bioluminescence "is diabolical in its own way", he says. ➤

60 days: the time it takes for plastic to float from the **US east coast** to the **centre** of the **North Atlantic gyre**



ERWAN GLEMAREC/SOLENT NEWS/REX FEATURES

Microplastics aren't good news for fish. The particles can reduce the efficiency of food absorption, and as they break down, release additives such as phthalates and bisphenol A, which can mimic hormones, as well as toxic flame retardants. Plastics also act like sponges for chemicals in seawater, absorbing organic pollutants such as polychlorinated biphenyls, and pesticides such as DDT. Studies suggest that pollutants stuck to plastics can poison fish.

We might feel these effects too. According to environmental toxicologist Lisbeth Van Cauwenberghe of Ghent University in Belgium, eating shellfish can expose you to 11,000 pieces of microplastic each year. Her tests show that commercially grown mussels contained an average of 0.36 microplastic particles per gram of tissue. Oysters contained slightly more. You would have to eat a lot of this seafood, says Van Cauwenberghe, "but marine microplastics could pose a threat to food safety".

So what will happen to all our discarded plastic in the long term? Rocks on Kamilo beach, a remote spot in Hawaii, may hold one answer. Here hikers often burn plastic in campfires and the sand is now strewn with "plastiglomerates", a mix of sand and artificial materials, all glued together with melted plastic that has cooled and hardened. Although these have so far only been found in relatively small amounts, it is conceivable that similar "plasticene" deposits might form on beaches where lava flows run, or where forest fires and extreme temperatures occur, says geologist Patricia Corcoran at the University of Western Ontario in Canada. Corcoran and her colleagues have collected hundreds of fragments of this new "rock" and suggest it

80 per cent of marine litter comes from **land**

Round the bend: a new home is welcome but waste plastic in the food chain is serious news

could eventually become embedded in the geological record.

Zalasiewicz agrees. "We are creating novel materials, which are very widespread in the environment. How do we know these will preserve?" Zalasiewicz works on fossilised plankton that leave a very small and delicate shell of organic polymers. "We know how they change when they enter the rock strata," he says: they lose hydrogen, nitrogen and oxygen, leaving carbon films, or become coated with iron sulphides or carbonates which leave fossil impressions in the strata. Similarly, as temperatures rise over time, pieces of buried plastic will begin to darken as the polymers break down, eventually releasing tiny amounts of oil and gas, and leaving a residue of brittle carbon. "On that basis, I see no problem in plastic drink bottles or CDs being preserved as fossils in the future – not exactly as they are, but as recognisable remnants," he says.

"What I would really like to see would be the preservation of vinyl long-playing records – good enough to preserve details of the grooves," says Zalasiewicz. And why not? Fossil worms preserved in 500 million-year-old Burgess Shale rocks show signs of fine grooves that would have created colours by refraction. These grooves are separated by less than a micrometre. Given that the grooves on LPs are around 20 times wider, there is a chance they, too, could survive, given the right conditions. "That would mean fossilisation of the patterns of sounds," says Zalasiewicz – music locked up in the geological record. So plastic could leave more than one type of rock for future generations to discover. ■

STEMMING THE FLOW

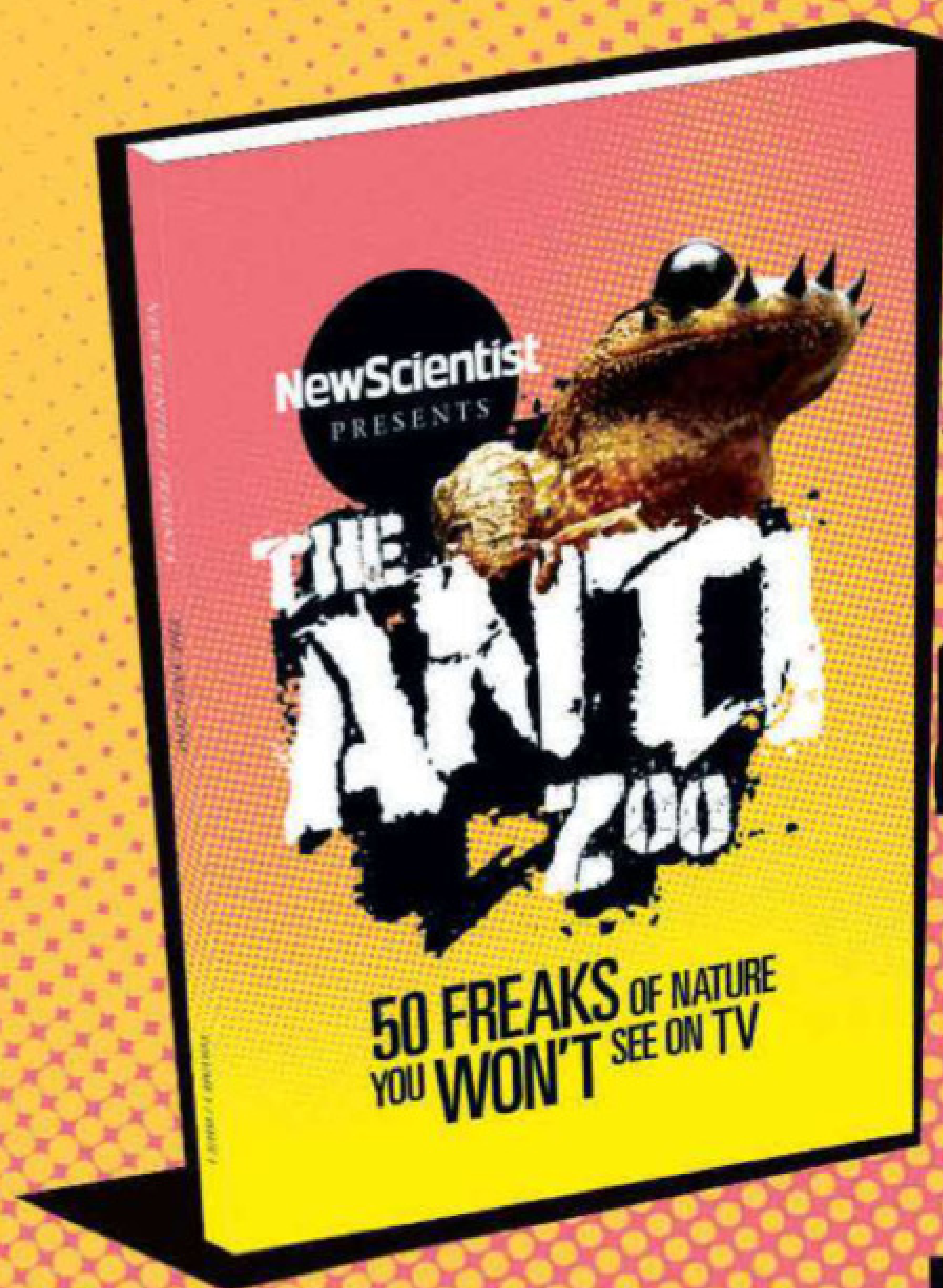
Huge amounts of plastic enter the oceans via rivers. Major components of this waste are fibres from synthetic clothes released during washing. It also contains microbeads, which are tiny plastic spheres used in many cosmetics. Water treatment plants can't filter them out, so they all end up in rivers.

In 2014, the state of Illinois passed the world's first ban on microbeads, after studies showed that the tiny plastic particles are a common pollutant floating on the surface of the Great Lakes. US senator Kirsten Gillibrand is pushing for legislation that will ban microbeads in all

US cosmetics. Some manufacturers have already acted: Unilever, Colgate-Palmolive, Procter & Gamble and Johnson & Johnson have all committed to eliminating these beads from their products.

Meanwhile, some groups are hoping to harvest plastic from the gyres. Last year, an organisation called The Ocean Cleanup completed a trial of a floating boom system in the Atlantic near the Azores. Based on the results, the group estimates that floating debris in a single gyre could be cleared in five to 10 years without harming wildlife. The organisation is now raising funds for a pilot project which could begin in 2018.

Christina Reed is a science writer based in Paris, France



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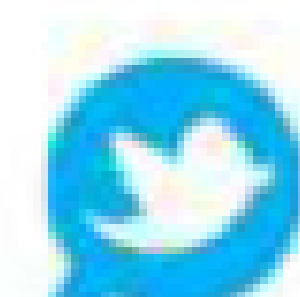
With the price of DNA sequencing plummeting, and the increasing smartness of handheld electronics and point-of-care diagnostics, the prospect of personalised medicine fine-tuned to a patient's genetic make-up no longer seems a far-off dream. Health apps are already giving the public unprecedented opportunities to monitor and manage their own fitness; in the future, we're promised, technology and genomics will combine to utterly change the patient's experience.

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**WE'VE HEARD THE HYPE. WE'VE WATCHED
THE BUBBLE BURST. BUT BITCOIN REMAINS
AS VOLATILE AS EVER. KADHIM SHUBBER
REPORTS FROM THE FRONTIER**

THE past year has seen a 21st century gold rush, and speculators have been falling over themselves for a piece of the action. The discovery of gold always brings a world in its wake and bitcoin – a virtual currency “mined” using a computer – is no exception.

There are miners chasing gold, crooks targeting the naive, black market traders operating outside the law and regulators trying to bring order to an upstart community.

Turn the page to meet some of the movers and shakers in this brave new world. ➤

THE MINERS

In late 2013, bitcoin miner Dave Carlson feared for the safety of his business. His 5000 square metre warehouse in Wenatchee, Washington, was packed with as much high-tech computing equipment as he could source and was churning out thousands of bitcoins – several million dollars' worth – each month.

But pickaxes were in short supply. As the value of bitcoins rose, producers of the specialist computers designed to mine them couldn't keep up with demand. "That's how much of a gold rush it was for this past year," Carlson says. "Our biggest fear was the smash and grab where someone would back a truck through the front of the building and load it up with as many of our rigs as they could get."

With a core team of 10, Carlson's small company, MegaBigPower, is one of the largest bitcoin mining operations in the world. At one point he was making \$50,000 an hour. Even a brief outage – lost equipment or internet connection – puts a big dent in your income.

Today, with the price of a bitcoin hovering around \$200 – down from its \$1000 high just over a year ago (see chart, page 39) – Carlson has a bigger problem: keeping his business afloat until the value goes up again. Bitcoin miners sell their bitcoin to pay costs, pushing bitcoin's price down further. But as the value of a bitcoin falls, it becomes harder and harder to break even, fuelling a downward spiral.

Bitcoin mines are dotted across the globe. Together they constitute one of the most powerful computing operations in the world. The total power of the bitcoin network – all the mining computers added together – is almost 4 million petaflops (a petaflop is the equivalent of 1000 trillion calculations per second). This is far greater than the world's top 500 super-computers combined. That kind of power comes at a price. Pioneers like Carlson have invested millions of dollars in the pursuit of the approximately 3600 bitcoin available to mine daily (see "What is bitcoin?", right). To keep running costs down, Carlson set up his Washington mine near the Columbia river, where his computers can be powered and cooled using low-cost hydroelectricity.

KnC Miner runs a mining facility in a disused helicopter hangar in the far north of Sweden. Even being sited just 80 kilometres from the Arctic circle isn't enough to keep the computers cool – it takes more than sub-zero temperatures to prevent 49,000 computer chips running round the clock from overheating. To help with the cooling, KnC Miner once flew 66 tonnes of heat sinks –



small devices that would dissipate heat from those chips – all the way from China. "They said a boat was much cheaper," says KnC Miner's Sam Cole. "But a boat takes six weeks. We needed them tomorrow because tomorrow we can print money with them."

Bitcoin mining is an unrelenting competition played at breakneck speeds. Every minute you spend sitting on your hands, or with your equipment sitting in boxes, you're

either losing money or someone else is striking it rich. "The cost of development is so high and you have to run at such a fast pace, it's effectively an arms race," says Cole. KnC Miner is open about its mining operation, to demonstrate its capabilities. "It's almost a show of weapons like in the cold war," he says.

It hasn't always been a battle of titans. Bitcoin mining used to be the preserve of bedroom hobbyists, who mined bitcoin on



WHAT IS BITCOIN?

Bitcoin is a virtual currency. As such, bitcoins are not issued by a central authority but are nevertheless accepted as payment by individuals and a growing number of businesses. Instead of being minted, they are created by computers on the bitcoin network. About 3600 bitcoins are added each day.

A currency requires safeguards against counterfeiting and double spending if people are to trust it. The breakthrough idea behind bitcoin – first posted to a cryptography mailing list in 2008 by a person or group going by the name Satoshi Nakamoto – is a way to have this without having a central authority.

The radical potential of a currency that is independent from governments and banks soon caught the attention of libertarians around the world, and the early bitcoin community was born. Now it's going mainstream.

BITCOIN'S BOOKKEEPERS

Trust in bitcoin is built into its bookkeeping. Whenever a transaction takes place – Alice sending a bitcoin to Bob, say – this is recorded in what is essentially a large database shared across all of the computers on the bitcoin network. This public ledger lets anyone see what transactions have taken place at any given time, though users remain anonymous.

The trust comes from the method used to guarantee that everyone has the same, up-to-date version of the database. And that's where the miners come in.

"Mining" means using a computer to bundle the records of a set of bitcoin transactions into what is known as a

block and adding it to the shared database, known as the block chain. But before the network accepts your block, your computer needs to solve a complex mathematical problem, partly based on the block's contents. The first miner to solve the problem gets to add the block to the block chain – and gains 25 bitcoins as their reward, worth around \$5000 at the time of writing.

The problem has been designed to take around 10 minutes for computers on the bitcoin network to solve. This ensures there is roughly a 10-minute delay between block chain additions, giving the entire network time to update itself when a block is added.

Miners often buy or sell mining capability through sites like CEX.IO – a process known as "cloud mining" – or gang together in mining pools, which helps to ensure they get a stable portion of the bitcoins created each day. As more miners with ever faster computers join the network, the difficulty of the problem adjusts automatically to maintain the delay.

The block chain is also extremely hard to tamper with, making it an accurate record of transactions. To make any alteration, you'd have to solve a problem for all blocks already in the chain, which is prohibitively difficult, or control at least 51 per cent of the hundreds of thousands of computers on the network.

However, without the backing of a central bank, bitcoin's value is volatile. In the last few weeks, its price has fallen, forcing several mining operations to shut down until the price rises again. Bitcoin needs to be worth at least \$320 to make mining profitable, says Jeffrey Smith of CEX.IO.

their personal computers. It was something anyone could do. But before long, as ever more powerful machines joined the race, ordinary computers could no longer keep up.

In the arms race that followed, specialist hardware was built. These chips do one thing and one thing only: mine bitcoin. Pans and pickaxes gave way to explosives, diggers and drills. Having the latest kit made all the difference. For a time, MegaBigPower had

chips that were 50 times faster than most miners had, says Carlson. "It allowed us to make pretty ridiculous profits for a while."

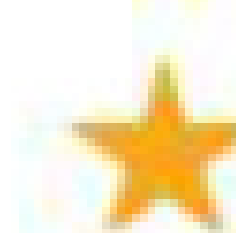
It's a different picture now. "We are coming to an end of an era," says Jeffrey Smith, chief information officer for CEX.IO, an online marketplace for bitcoin services. "The investment in mining is huge, mining operations are gigantic, and in my opinion, only large investors will survive."

THE OUTLAWS

Just as plucky pioneers in the California gold rush gave way to industrialised operations, bitcoin mining has become dominated by big money. But the financial incentives have also attracted outlaws. Hackers have targeted individual bitcoin users, bitcoin exchanges and, in at least one case, the flow of traffic across the internet itself, in pursuit of profit.

Between February and May last year, for example, a hacker took control of a router – a computer that directs internet traffic – at a Canadian internet service provider and redirected all mining traffic to a mine controlled by the hacker, effectively siphoning off other miners' earnings.

By hijacking the traffic, the hacker told the mining hardware "you're only going to mine the coin that I tell you to mine and by the way I'm keeping all the profits", says Pat Litke of Dell's SecureWorks Counter Threat Unit, who



"THE BIGGEST BITCOIN HEISTS HAVE BEEN BANK JOBS RATHER THAN ROADSIDE HOLD-UPS"

detected the attack with his colleague Joe Stewart. They believe the hacker was an employee of the service provider and that they made around \$83,000 in four months.

However, the biggest bitcoin heists have been bank jobs rather than roadside hold-ups. Just this month, for example, European bitcoin exchange Bitstamp lost 19,000 bitcoins, or more than \$5 million, in a hack.

But that pales in comparison to what some consider to be the biggest bank robbery ever. On 24 February last year, Tokyo-based Mt. Gox, bitcoin's most famous exchange, went offline. Four days later, its CEO Mark Karpelès admitted that around 850,000 bitcoins had been stolen – the equivalent of losing about \$500 million at the time. With a Tokyo police investigation ongoing, as well as bankruptcy proceedings and several lawsuits, exactly how Mt. Gox lost so much money is still unknown. Unnamed police sources in recent Japanese media reports have suggested the theft was an inside job. And Jason Maurice at security firm WizSec in Japan – who himself lost around \$40,000 when the exchange collapsed – believes an insider took advantage of Mt. Gox's disorganised accounting procedures.

Maurice's assessment fits with what we do know. In June, Karpelès finally broke his ➤

silence in an interview with *The Wall Street Journal*, and spoke of struggling to meet the demands of running a business.

But while the collapse of Mt. Gox is often cited as an example of bitcoin's immaturity, the year-long market manipulation that preceded it is less well known. Maurice's firm has been investigating the activities of two trading bots – dubbed Willy and Markus – that used fake money to buy almost 570,000 bitcoins from Mt. Gox. Some think that this directly led to an artificial inflation in bitcoin's value.

"Karpelès was too busy doing other things to notice what was happening in the background," says Maurice. "If exchanges let their guard down for a minute there's going to be a compromise." The bots suggest Mt. Gox never had its defences up in the first place.

Karpelès, who has since started a new web-hosting business – which doesn't accept bitcoin payments – declined to comment on the theft when contacted by *New Scientist*. With regards to Willy and Markus, however, he claims that such things aren't uncommon. "The market is quite often the home of market manipulation," he says.

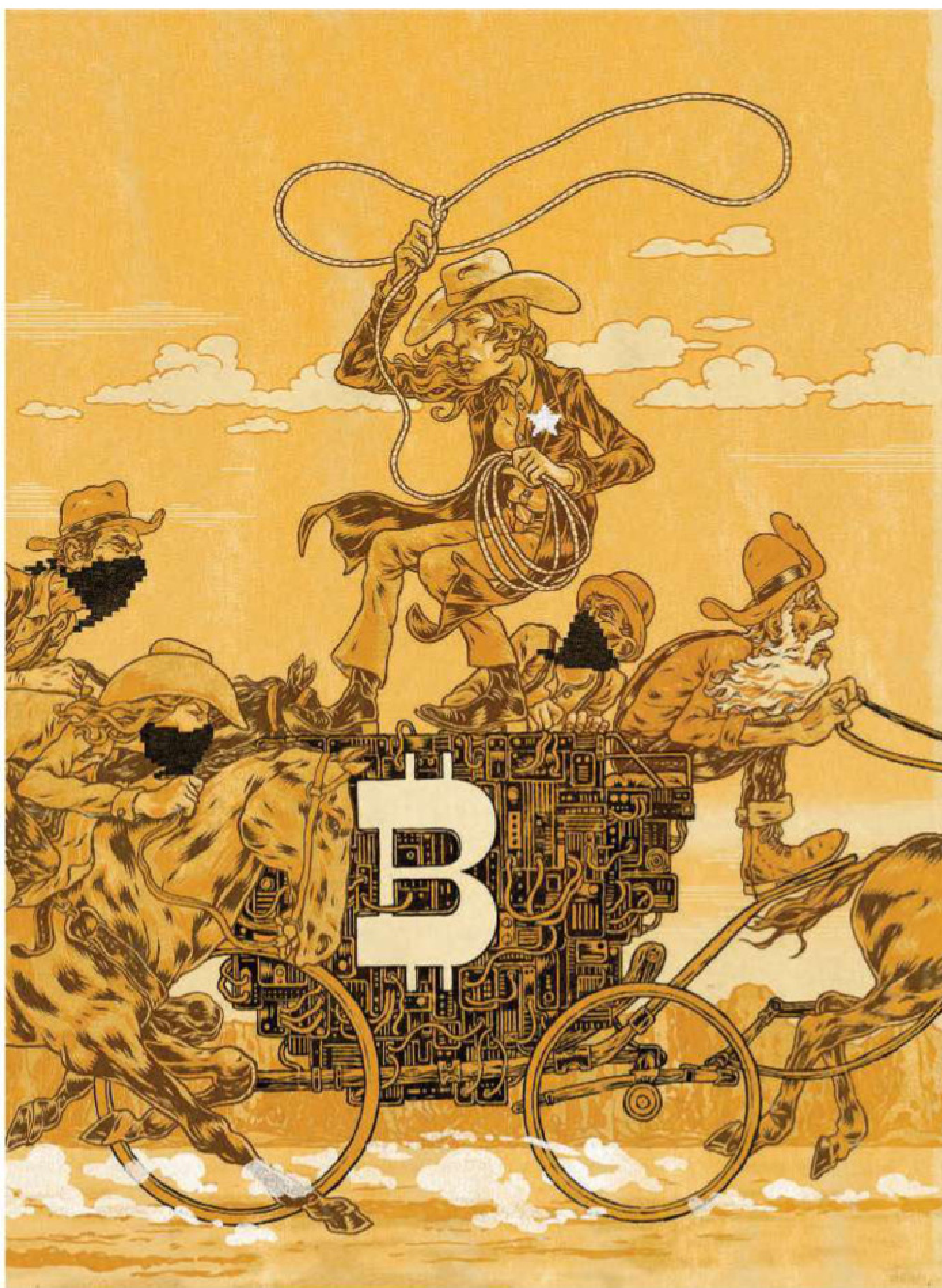
Some worry that large mining pools could also destabilise the whole enterprise. CEX.IO, which operates what was once the largest mining pool, GHASH.IO, has been criticised by the bitcoin community for controlling too large a piece of the total network. Worse, with bitcoin miners now being squeezed by the falling price, only a handful may survive, making the bitcoin network more centralised and vulnerable to attack.

Another concern is bitcoin's links to the black market. Since bitcoin transactions aren't tied to real-world identities, the currency allows illicit goods to be traded online anonymously.

Until recently, the most popular online hub for such trade was Silk Road 2.0. Like Amazon or eBay the site had trusted sellers and user reviews, but over 80 per cent of the thousands of products for sale were illegal drugs. Sites like Silk Road 2.0 – and there are thought to be at least 35 similar drug marketplaces – are inaccessible from normal browsers like Chrome or Internet Explorer. Instead they are hidden on a part of the internet, known as the dark net, that can only be visited through a browser called Tor.

Nevertheless, in the first four months of 2014 the highest-earning trader on Silk Road 2.0 made \$7 million, according to research by Jamie Bartlett at UK think tank Demos.

Hiding on the dark net and using bitcoin



ANDREW DECRAFF

makes it harder to hunt down the site's administrators. But it's not impossible. The original Silk Road was run by an individual going by the name Dread Pirate Roberts. In October 2013, the site was shut down after the FBI arrested its alleged creator, Ross Ulbricht. In November 2014, the authorities caught up with Silk Road 2.0, shutting that down too.

But like a game of whack-a-mole, when one site goes down, others spring up in its place. "Dark net marketplaces are selling many more drugs than they were when the Silk Road was originally busted," says Bartlett.

This is the seedy underbelly of bitcoin, but it mirrors a deeper anti-authoritarian ideology. "For its advocates, bitcoin is a strike for the individual and for individual liberty against the overweening and overbearing power of central governments," says Bartlett.

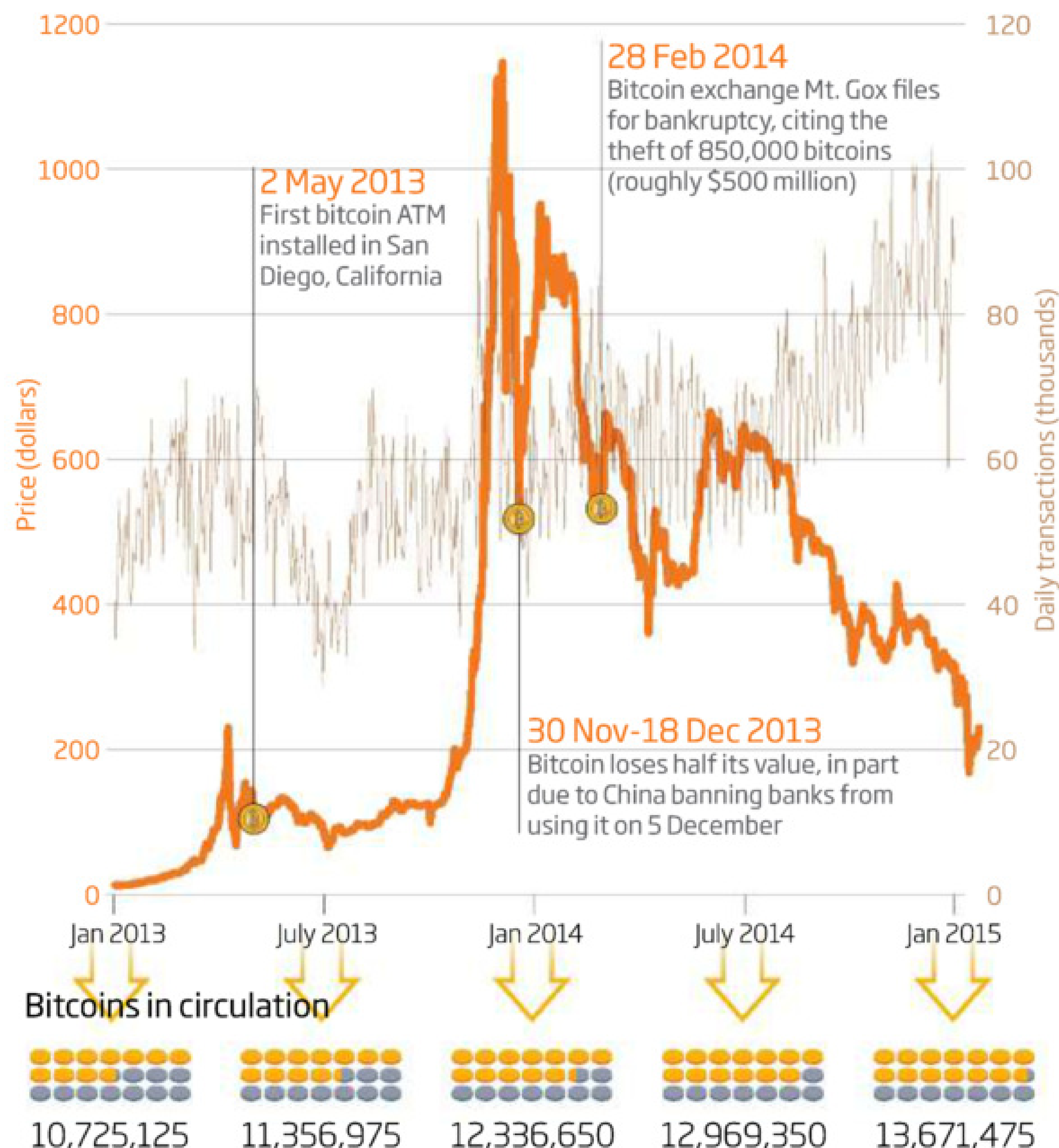
THE REGULATORS

In response, governments are doing their best to assert some control. Different authorities have taken different approaches, however. For example, Bolivia outlawed bitcoin in May last year and California legalised it a month later. In the UK, Chancellor George Osborne has pledged to create a "global centre of financial innovation" in part by encouraging bitcoin businesses. Admittedly, that encouragement has consisted mainly of positive words. In practice, businesses trading in bitcoins or offering bitcoin services find it hard to get insurance and bank loans.

However, it is New York's attempts to regulate bitcoin by requiring businesses to

After the gold rush

The value of bitcoin peaked at over \$1000 in late 2013 amid media hype, although its value has since fallen - recently dropping below \$200 for the first time in more than a year. Meanwhile, the number of daily transactions continues to grow



About 3600 bitcoins are created each day as rewards to miners for performing the computations required to update the global ledger of bitcoin transactions. The rate at which coins are created will fall over time until an upper limit of 21 million coins is reached, which is not expected to happen for at least 100 years

apply for a “BitLicense” that has attracted the most ire. The proposals, spearheaded by the Superintendent of Financial Services for New York, Ben Lawsky, would broadly put bitcoin in line with existing banking regulations. They require businesses to keep a record of any bitcoin transactions for up to seven years, including the names and addresses of their customers and, where possible, the recipients of a transaction.

For many it’s a policy that undermines much of what bitcoin represents. Yet Lawsky and others cite what happened to Mt. Gox as an example of the dangers of leaving the industry unregulated. In public statement, Lawsky has argued that “setting up common sense rules of the road is vital to the long-term future of the virtual currency industry”. Much of the debate is the predictable back-and-forth

when any industry is first regulated, but it’s a sign of how far a certain portion of the bitcoin community has come from its radical roots.

Far from being the preserve of radicals, bitcoin businesses are now backed by over \$400 million of venture capital, and that number is increasing. The largest bitcoin companies now have former bankers and regulators on their payroll.

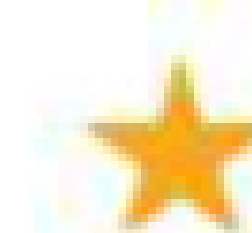
Bitcoin ATMs are also popping up around the world. Like online exchanges, these allow anyone to buy bitcoin with regular money. And the list of places that accept bitcoin as payment – which now includes the likes of Microsoft, PayPal and Expedia – grows by the month. Even small businesses are seeing the advantage of accepting bitcoins because it lets them avoid the high fees paid to credit card companies.

THE NEXT PIONEERS

However, bitcoin’s impact could be felt far beyond its role as a currency. The network behind bitcoin provides trust in the currency without the need for a central bank – and could do the same for any number of applications. In theory, the bitcoin network – or others built on the same principles – can back the exchange of any item. It could be used to verify the sale of cars or houses, say.

OpenBazaar, for example, is an eBay-like marketplace that nobody controls. Instead, by running the software on your computer you connect directly with other buyers or sellers. The bitcoin network – which verifies all the transactions – provides trust in the system.

A similar idea drives the development of Lighthouse, a crowdfunding site built by bitcoin developer Mike Hearn. It will allow anyone to create a crowdfunding campaign



“BITCOIN’S IMPACT COULD BE FELT FAR BEYOND ITS ROLE AS A CURRENCY”

for any project they desire, for free. “You don’t even need a site, really,” says Hearn. As long as the transactions are recorded by the bitcoin network, pledges could be made by email.

More radical still is Ethereum, a project built on a new network based on bitcoin. Its transactions can encode arbitrary contracts that could be used for voting systems or business agreements, say. Its designers hope to reimagine civil law, with computer code replacing legalese, programmers taking the place of lawyers, and contracts enforced by computers rather than courts. “It effectively allows you to digitise law itself,” says Ethereum’s Gavin Wood.

With the growth of such projects, the bitcoin network could undermine not only the financial world as we know it, but anything that can be reduced to lines of code – and that means pretty much everything. While miners churn out thousands of bitcoins each day and mainstream bitcoin companies model themselves on existing financial services, programmers are creating tools that let individuals interact and trade directly, without the need for third parties. The gold rush may have peaked, but the new frontier is still largely uncharted. ■

Kadhim Shubber is a reporter at The Financial Times



THAW POINT

Far from shrinking as scientists expected, the sea ice around Antarctica is growing. What's going on, asks **Stephen Battersby**



currents to giving a nudge to the teetering West Antarctic ice sheet, whose collapse would raise sea level by several metres.

Vast amounts of water are locked away in the great ice sheets in Antarctica. Almost the entire continent is covered by ice sheets that are nearly 2 kilometres thick on average, hiding whole mountain ranges. Where this ice slips off the land into the sea, it forms floating ice shelves hundreds of metres thick. Half the coast is surrounded by ice shelves, some of them immense.

Beyond lies the sea ice. It is distinct from the ice shelves, because it forms when the surface of the sea freezes and is about a couple of metres thick on average. Unlike in the Arctic, in Antarctica almost all the sea ice melts in spring and reforms each autumn and winter (see “Polar opposites”, page 42).

Baffling behaviour

Now the frozen continent is warming up – with unexpected consequences. As recently as 2007, the official prediction was that the ice sheets would grow over the 21st century, because higher snowfall would more than compensate for higher ice losses. In reality, satellite gravity measurements show the ice sheets have already started to shrink.

Ice shelves are not following the script either. They have been thinning faster than expected, and several have disintegrated abruptly. The collapse of the enormous Larsen B ice shelf in 2002 shocked most glaciologists.

Most baffling of all is the behaviour of the sea ice. According to the majority of climate models, it should be shrinking as the air and waters around Antarctica warm. And in some places, such as in the Amundsen and Bellingshausen seas west of the rapidly warming Antarctic Peninsula, the sea ice is doing just that. But in others, it is growing (see “Thick and thin”, right). Overall, the area covered by sea ice in winter is slowly increasing.

This is good news. Although Antarctic sea ice is mostly around in the 24-hour darkness of winter, there are still several million square kilometres of it left in the spring when the ➤

The world is set to defrost. All over the planet glaciers are retreating, while tundra thaws. The ice caps of Greenland and Antarctica are looking fragile, and the Arctic’s once-vast raft of sea ice is shrinking at an alarming pace. And down south, in the seas around Antarctica, the sea ice... well... er... seems to be growing.

In the few decades we have had satellites keeping watch, the area of the Southern Ocean covered by sea ice in winter has grown bigger, hitting record levels in recent years. The increase is small, but it is surprising – and

something of a mystery. “The Arctic is doing exactly what we would expect,” says Paul Holland of the British Antarctic Survey. “The Antarctic is not.”

A couple of years ago, Holland thought he had cracked the mystery: stronger winds were to blame, his team concluded. But now Holland thinks they got it wrong. So what in all the icy hells is going on down there? The answer matters to more than penguins. If or when the sea ice starts to shrink instead of growing, it could have knock-on effects around the world, from interfering with ocean

PAUL NICKLEN/NGS

sun is high. By reflecting a little more sunlight, the extra spring sea ice should slightly slow the warming of the seas around Antarctica. (In contrast, the Arctic Ocean is absorbing more heat and warming faster as the area of summer ice shrinks – a positive feedback.)

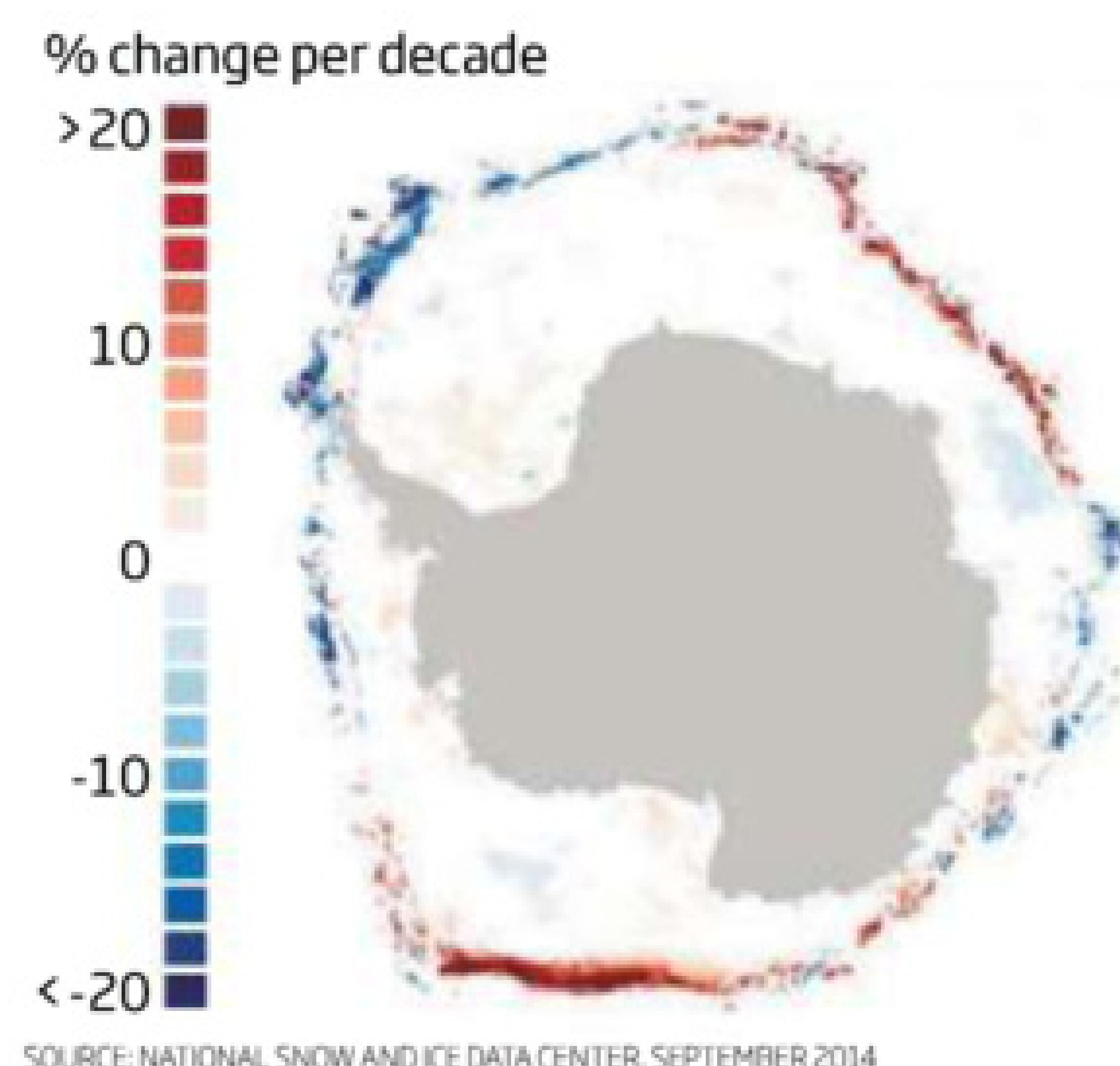
Indeed, satellite measurements show that the oceans around Antarctica are reflecting 0.9 per cent more sunlight in summer, says Norman Loeb of NASA's Langley Research Center in Hampton, Virginia, whereas the Arctic is absorbing 5 per cent more. The big question is what happens next. "If instead it were shrinking like the Arctic, you would imagine a significant effect," says Holland.

The loss of Antarctic sea ice would not only lead to more warming, it would also affect ocean currents. As the sea ice forms in winter, extra salty water is left behind. This cold, dense water sinks down to the ocean depths and flows around the globe before eventually slowly surfacing again in tropical seas.

The waters around Antarctica, though, are becoming fresher and less dense because the ice shelves are melting faster, and more snow and rain now fall on the Southern Ocean. This is hindering the sinking process. If the sea ice retreats then sinking might stop altogether, changing ocean circulation around the globe. That would affect sea temperatures and thus

Thick and thin

Sea ice concentration has declined in places around Antarctica, especially around the West Antarctic Peninsula, but grown in others



the climate in ways that are hard to predict.

So the sea ice is important, but right now we have no idea whether it will continue to slowly increase over the coming decades, or suddenly disappear. "There is a pressing need to understand this," says glaciologist Sharon Stammerjohn of the Institute of Arctic and Alpine Research in Boulder, Colorado.

In 2012, Holland thought his team had the solution. "We made the simple claim that stronger winds from the south were carrying cold air off Antarctica, and dragging ice north,"

he says. In autumn and winter, this would create gaps where new ice could form as well as cooling exposed water. A study of 20 years of satellite images seemed to support the idea.

It seemed like a satisfying explanation for the sea ice paradox, given that there is no doubt that the winds around Antarctica have been strengthening (*New Scientist*, 20 July 2013, p 34). This is partly due to global warming and also partly the result of the hole in the ozone layer created by our pollution. Natural variability may also play a part.

Blowing in the wind

But when Holland looked again at what was happening, he began to doubt the wind explanation. This time, he looked at ice changes in a different way. Instead of focusing on the area of sea ice, he looked at how fast it was melting or forming. This is a more direct way to see the influence of climate changes, Holland says. "For example, warming wouldn't directly decrease the amount of ice in a season, but rather its melting rate."

From this viewpoint, there is no longer an autumn lockstep between wind and ice. The most glaring clash is in the Bellingshausen Sea. There, the autumn winds have become stronger. They blow from the north, which must be shoving more ice in towards the coast, keeping it from spreading, as well as carrying warmer air from temperate regions. Indeed, the overall area of autumn sea ice here has declined, which would seem to fit with that idea. But if the stronger winds were the key factor affecting ice growth, the ice should be growing more slowly. In fact, during autumn it is growing faster than it did a few decades ago. "That destroys my earlier work," Holland says.

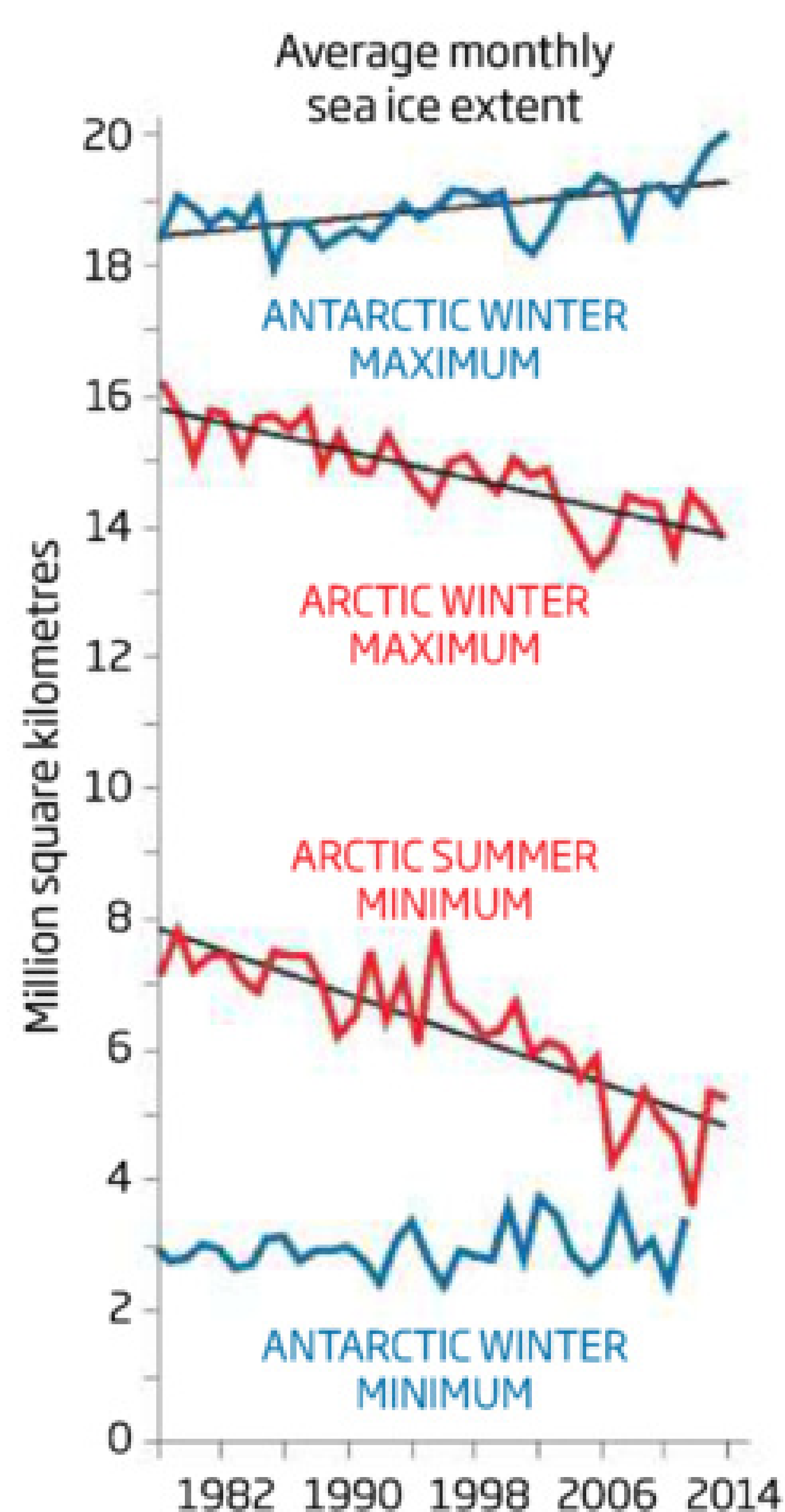
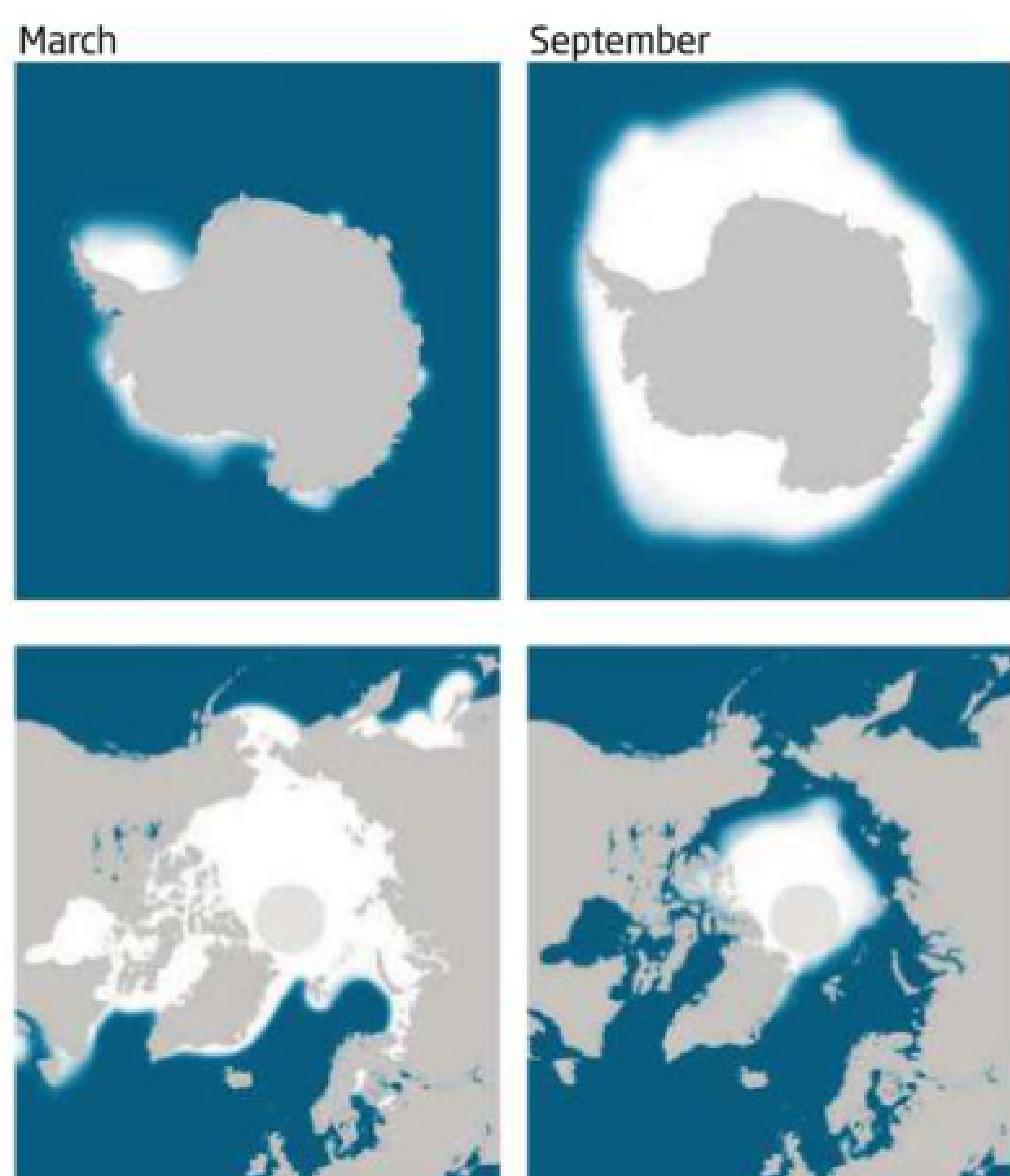
He now thinks that to understand these changes in sea ice, we need to focus on what's happening in the spring. In the Bellingshausen Sea, ice is now retreating earlier in the springtime, letting the ocean absorb more solar heat. That warming should delay the regrowth of ice – accounting for the decline in ice area in autumn. But when the ice does grow back, it does so quickly, because now the ocean is open to the air, it rapidly loses its heat again.

In other words, sea ice has a tendency to bounce back from big spring losses. This was first noted in Antarctica by Stammerjohn, in a 2008 study that looked at how ice is changing region by region and season by season.

These feedback processes also happen in the Arctic, says Dirk Notz at the Max Planck Institute for Meteorology in Hamburg,

Polar opposites

In Antarctica the extent of winter sea ice has increased slightly. In the Arctic, the extent of winter and summer ice has dropped dramatically





MARIA STENZEL/NGS

“There is a pressing need to understand what’s happening to the sea ice”

Ice work: studying sea ice is extra tricky in Antarctica, where thick snow blocks radar

Germany, which may explain why summer sea ice there seems to recover somewhat every time it hits a new record low. None of this even begins to explain why Antarctic sea ice is growing overall, but if these trends originate in the spring, that’s where we should look for what’s really causing them, says Holland.

“I hope it is a trail that will lead to the truth.”

Notz, however, is not convinced that Holland is right to focus on whether sea ice is melting or forming faster or more slowly than it used to. “He is looking at a change in a rate of change,” he says. “I do not think it’s a measure that is important.”

So Notz’s team thinks that the wind explanation still holds. The reason most climate models have been projecting sea ice losses, they argue in a study published in December, is that they are too coarse-grained. They miss details of Antarctic topography that deflect winds northwards and spread out sea ice, allowing more ice to form.

However, there are almost certainly other forces at work. Changes in deep ocean circulation are bringing in more warm water

around West Antarctica. This is thought to be the main reason for the thinning of the ice shelves there, says Stammerjohn, and may be speeding up the loss of sea ice too. Elsewhere, she suggests, less ocean heat may be welling up, allowing more sea ice to form.

And could the rush of fresh water from the thinning ice shelves be playing a part, too? Fresher water not only freezes more readily, it is also more buoyant, so a surface layer of fresher water may be stopping warmer water rising to the surface.

Blind satellites

However, the greatest increase in fresh water is around the Amundsen Sea, where the glaciers are retreating fast, yet sea ice there is still shrinking, too. So the fresh water appears to be having little effect, Stammerjohn says, although the case is not entirely closed.

In the end, it is not so surprising that we are struggling to understand Antarctica. This region is a lot more complex than the Arctic, yet observations are much scarcer because the

region is so remote and forbidding. Simply building instruments tough enough to survive the conditions is difficult, let alone deploying them. Even satellites see less here. In the Arctic it is possible to use radar altimeters to measure ice thickness, but in the Antarctic there is a lot more snow sitting on the ice, which absorbs the radar signal. Yet monitoring ice thickness is critical for understanding what’s happening. Robot subs are now being used to rove under the ice to measure its thickness, but so far they provide only a snapshot of a small area.

Besides better observations, we need better models. Trying to build climate models that match what’s happening in Antarctica may be the most productive way to resolve the debate about the causes of the sea ice increase. “It’s a lot of things working against or for each other, which makes it hard to get one’s head around what really will happen,” says Notz. But if he is right about the role of small-scale topography then we are nearly there – the key will be improving model resolutions from 100 kilometres or so down to a few kilometres to get the wind directions right.

Holland thinks we’re still far from the answer, but he too thinks better modelling is the way forward. “When we get a model that matches what happens in the spring, we can look in the model to see what it’s doing.”

In the meantime, with many of the other effects of global warming kicking in much sooner and harder than we expected, let’s keep our fingers crossed that the stubborn seas around Antarctica continue to buck the trend for a few more decades. Sometimes it’s good to be wrong. ■

Stephen Battersby is a correspondent for *New Scientist* based in London

DISTINCTLY DIFFERENT

ANTARCTICA

Land and ice surrounded by ocean – sea ice can drift into warmer waters and melt

Sea ice is temporary – almost all of it melts each summer

Winter ice area has increased slightly. Volume change unknown

Because it is dark in winter, the extra ice is only reflecting a little more solar heat

ARCTIC

Ocean surrounded by land – sea ice is mostly locked in

Sea ice is semi-permanent – about half the ice survives the summer

Area of summer ice has halved and volume shrunk by three-quarters

Exposed seas are absorbing more solar heat in summer

The greater good

Figuring out what makes us behave selflessly is a tricky business, finds **Kate Douglas**

Does Altruism Exist? Culture, Genes, and the Welfare of Others by David Sloan Wilson, Yale University Press, \$27.50/ £16.99

The Altruistic Brain: How we are naturally good by Donald W. Pfaff, Oxford University Press USA, \$24.95/£16.99

IN 1851, Auguste Comte, the French philosopher and father of sociology, coined the word *altruisme* (from the Latin for “others”) as part of a drive to create a non-religious religion, based on scientific principles.

He defined it as “intentional action, ultimately for the welfare of others that entails at least the possibility of either no benefit or a loss to the actor”, recognising it as one of the two most important findings of modern science, with the discovery of the motion of

Does giving money to people who beg constitute true altruism?

Earth. At that time, studies of animal behaviour and phrenology led him to locate egotistical instincts at the back of the brain, altruistic ones at the front.

Today, we have a far more sophisticated knowledge of the neurological and biochemical factors that underpin benevolent behaviour. And this science forms the bedrock of two books aimed at general readers – but also at those who, despite the research, still doubt the existence of altruism.

However, the books may end up inadvertently providing more ammunition for the naysayers. Take *The Altruistic Brain* by neuroscientist Donald Pfaff. On solid scientific ground, he builds a five-step theory of how altruism occurs, which hinges on an idea that is both unconvincing and counterproductive. Pfaff argues that to act altruistically you should first visualise the recipient of your goodwill, then

mentally transform their image into your own, “from angle to angle and curve to curve”.

How narcissistic!

At the core of evolutionary biologist David Sloan Wilson’s *Does Altruism Exist?* is another

“What matters is that humans can coordinate activities in the right way to achieve common goals”

contentious idea: altruism has evolved as the result of group selection. But Wilson argues his corner masterfully, providing a pithy riposte to the belief that natural selection occurs only at the level of the selfish gene: “Selfishness beats altruism within groups. Altruistic groups beat selfish groups,” he says.

In other words, we cooperate when doing so gives our team the edge. That doesn’t sound very selfless either.

Wilson acknowledges this, but argues that thoughts and feelings are less important than actions.

According to evolutionary theory, pure altruists do exist, but it doesn’t matter why people choose to help others – their reasons may be opaque even to themselves. What matters is that humans can coordinate their activities in just the right way to achieve common goals. Other animals do this too, but we are masters. “Teamwork is the signature adaptation of our species,” he says.

Pfaff goes further, insisting that our brain biology “compels us to be kind”. He believes this knowledge alone will inspire individuals to be more altruistic. His desire to create a better world is admirable and some of his ideas are interesting, but Wilson’s analysis is more coherent and nuanced.

While it is in our nature to be altruistic, Wilson says, we also have a healthy regard for self-interest and a resistance to being pushed around. Which predisposition comes to the fore depends on the environment in which we find ourselves. Ethics, he says, cannot be taught at individual level, but are “a property of the whole system”.

Wilson’s fascinating gallop through religion, economics, politics and everyday life reveals many ways to activate altruism. Take his Neighborhood Project, where he designs environments to select for prosocial behaviour. By doing this, he and others promote measures to help groups function better, by, say, encouraging equality or discouraging free-riding. Not pure altruism, sure, but sound science. Comte would be impressed. ■



GIACOMO PIRROZZI/PANOS

None more black

Can you paint nothing? **Sumit Paul-Choudhury** stares into the void

NanoBlck-Sqr #1

Carroll/Fletcher Gallery, London

Until 21 February 2015

Adventures of the Black Square:

Abstract Art and Society 1915-2015

Whitechapel Gallery, London

Until 6 April 2015

IT DOESN'T look like much. But then, that's rather the point.

The work Belgian artist Frederik De Wilde is showing, in a dimly lit basement just off London's Oxford Street, is a black square. Not just any black, either. Viewing

NanoBlck-Sqr #1 for the first time, it's hard to decipher what you're looking at. You might instead find yourself contemplating phosphenes – the glowing blobs that appear before your eyes when you stare into utter darkness.

De Wilde's work is made of carbon nanotubes fixed to an aluminium "canvas" by means he won't disclose. These, the blackest substance ever made, reflect less than 0.01 per cent of the light that hits them; black paint reflects up to 10 per cent.

As well as being very black, it's very fragile – the white frame is powdered with black dust – and very expensive, so every viewer has a chaperone. Once your eyes adjust, you can make out faint patterns. De Wilde applied the carbon by hand, so it is thicker in some places.

"The nanotubes are 99.99 per cent air, and only 0.01 per cent carbon," he says. "So basically you are looking at nothing." They were supplied by researchers at NASA and Rice University in Houston, Texas, with whom De Wilde has collaborated for some years.

Calling the future: the geometry of radio masts inspired abstract art

Ultramodern though the materials are, De Wilde is reprising an old idea. A hundred years ago, Russian artist Kazimir Malevich exhibited a collection of monochromatic geometric shapes at a groundbreaking exhibition in St Petersburg (then Petrograd). The most notorious was a large black square which he placed exactly where a traditional Russian Orthodox household would have displayed holy icons.

"The black square is like an atomic clock, the reference for time - black becomes the reference for society"

Malevich hoped that the 1915 show would liberate art from any obligation to depict the real world: these were not paintings of anything. It worked. The black square was "a void which erased the past and freed artists from history, allowing them to stride into the future", says Iwona Blazwick, director of London's Whitechapel Gallery, whose new show celebrates its legacy.



ROBIN REEVE FOR CARROLL/FLETCHER

Artists, graphic designers and architects of that revolutionary era were attracted to the idea that their work need not draw from real life. They also found such abstraction apt for their times, in which modern communication technologies were overthrowing orthodoxies of all kinds. Stylised designs for loudspeakers and photographs celebrating the geometries of radio masts took their place beside Malevich's stark, suprematist works.

A century of experimentation followed, embedding abstraction firmly into the artistic canon, as the Whitechapel's *Adventures of the Black Square* compellingly illustrates. Perhaps overly so: some feel the black square's power has dissipated. De Wilde thinks it's about time the idea was rebooted; hence his own, yet more extreme, black square.

"I wanted to make a connection with Malevich and the political background when *Black Square* was created," he says. "We are living in another time, but the situation is recurring, with all this polarisation in society. I think the black square is almost like an atomic clock, the reference for time – black becomes the reference for society, like the black flag was a symbol for revolution."

De Wilde wants to apply his "nanoblack" to three-dimensional forms: its apparent abolition of depth may yield startling effects. But he isn't the only artist exploring the outer limits of blackness. He bristles when I refer to plans for sculptor Anish Kapoor to use "vantablack", claimed by its maker, Surrey NanoSystems, to be even blacker. It seems the quest for the ultimate portrait of nothing is a competitive one. ■

Academia Feature



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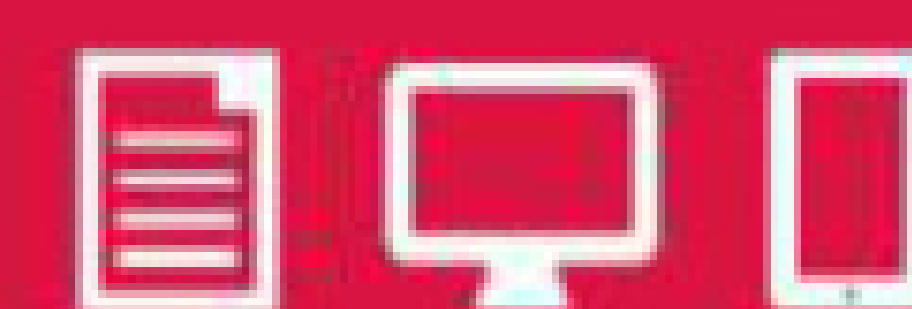
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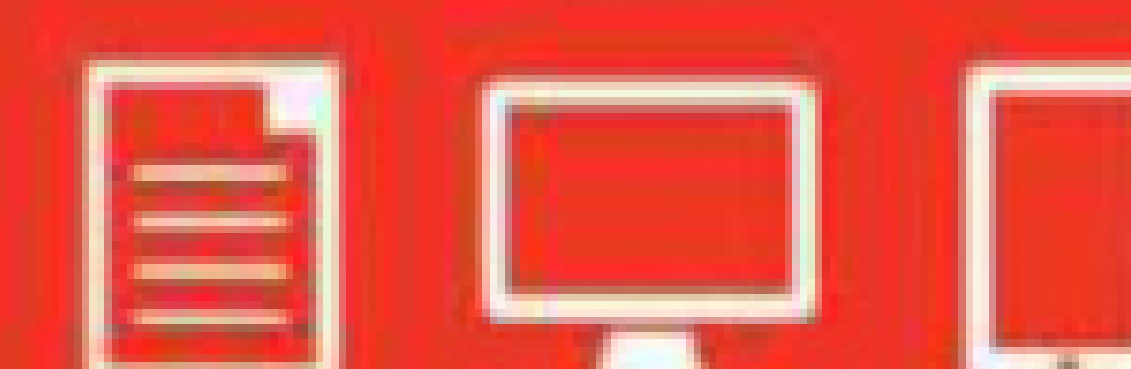
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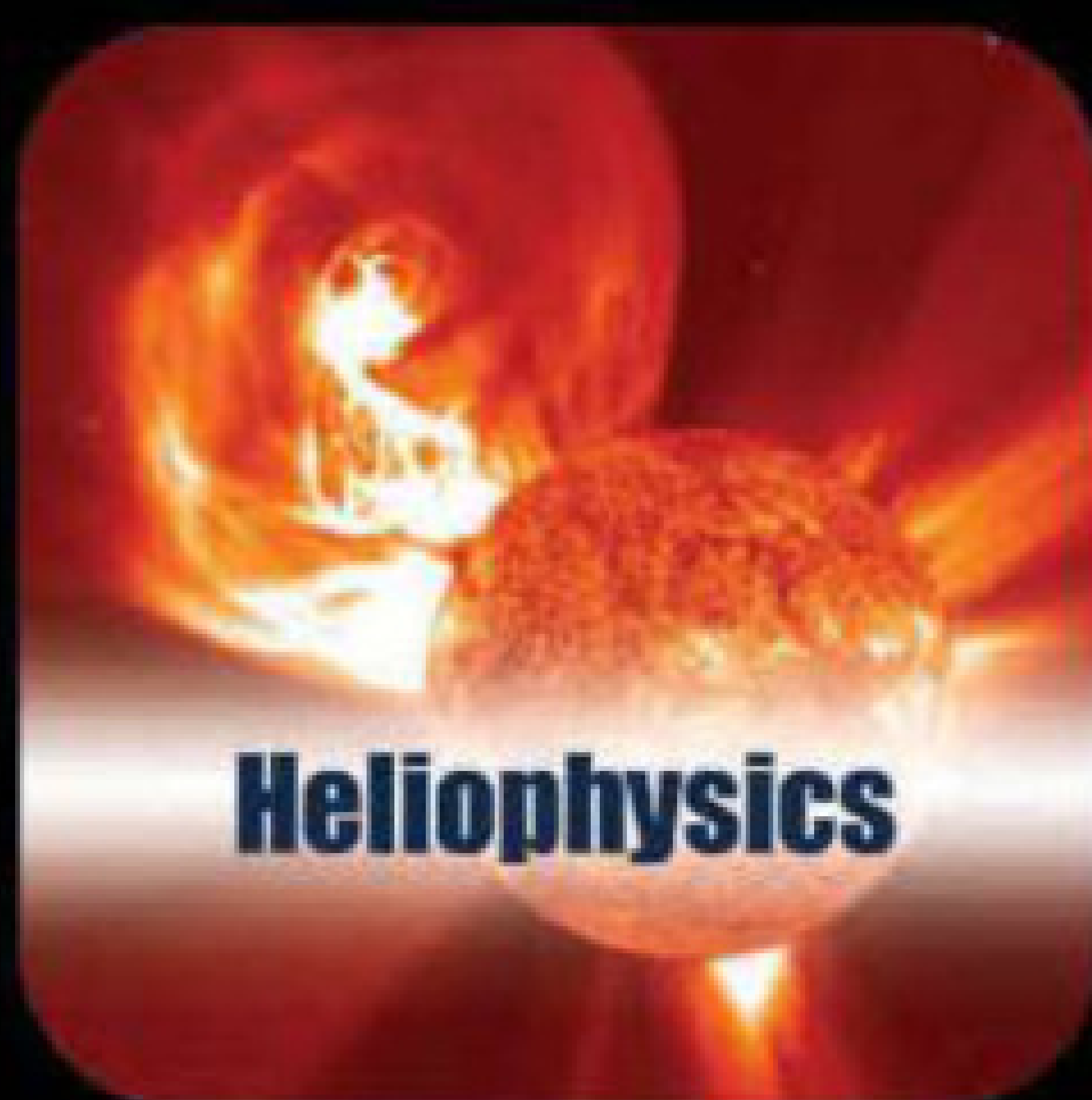
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Autism correction

From Penny Jackson

I was very disappointed with your article about a brain test to diagnose autism (6 December 2014, p 6). Autism is not a “psychiatric illness”. Such a term is grossly offensive to people with autism who are struggling to have it accepted as a different way of thinking, rather than simply a defect. In addition, “illness” is not a word I ever recall hearing in medical descriptions. The study was not about emotions, but sense of self.

Salisbury, Wiltshire, UK

The editor replies:

■ Apologies. We should not have referred to autism as a psychiatric illness. In addition, we should have made clear that the focus of the study was on self-representation rather than emotion. These points have now been corrected in the online copy.

Great adaptations

From Kimon Roussopoulos

Colin Barras considers whether adaptation helps evolution, but experts seem unsure whether this happens or matters (17 January, p 26). Surely plasticity can enormously influence evolution with only an indirect link to heritability? Take your example of fish. Suppose the water dries up, but many fish survive marginally with the help of plasticity, long enough to reproduce. If one fish then mutates helpfully to produce proto-legs or lungs the advantage is likely to give its descendants a chance of dominance.

If the mutation had occurred in a swimming population those fish would be more likely to be disadvantaged. Conversely, if the fish couldn't survive on land in the first place, there'd be no opportunity for the mutation to grant any benefit.

Surely plasticity is likely to be a key catalyst for evolution,

enabling a population to last in a hostile environment long enough for a benign mutation to spread.
Cambridge, UK

From Steve Morris

Reading Colin Barras's article on adaptation, I couldn't avoid the conclusion that there was more than a touch of “straw man” in this hypothesis. I can't see where the key difference is to separate it from what we have been teaching for years in evolution courses.

The traits that allow plasticity in the first place are going to be of the continuous type, which usually vary along a normal distribution. Selection moves the mean of these in the direction favoured by whatever selection pressure is applied – in the case of the fish, less water.

This is the hypothesis behind the divergence in “Darwin's finches” – a group of closely related species found on the Galápagos Islands. Subsequent selection over generations will alter the gene pool, both to represent the more favourable genotypes from the original population and to favour any mutations that further improve fitness in the new environment.
Whitland, Carmarthenshire, UK

What time is it now?

From Ian Beaver

I enjoyed Laura Spinney's exploration of the perception of time (10 January, p 28). We older people are commonly heard to complain that time seems to pass more quickly than when we were younger. I had presumed that this is due to life being increasingly routine, with fewer memorable moments in the near past to look back on. But could it be because there is less “stretchiness” in our time experiences, as Spinney describes it? Perhaps this stiffness is because our lives have fewer novel or stressful moments during which time is perceived to be slowed. More pessimistically,



perhaps it's because we have lost our ability to “slow down time” during those moments.

If David Melcher's experiments with shuffled movie clips showed no correlation with the subject's age, then there is hope that we could put the brakes on our perception of time by getting out of our routines and injecting some excitement into our days. Maybe I should buy a motorcycle?
Bethesda, Pembrokeshire, UK

From Jo Egerton

Questions of time are perennially fascinating, and Laura Spinney's article is no exception. As my mother's Alzheimer's progresses, her perception of passing time has expanded – something many people have observed in relation to the disease. Having shared a memory with me, 10 minutes later she may refer to it by saying, “As I told you last week...”

This led me to wonder whether our perception of time is linked to how difficult it is to recall a memory. With the atrophy of brain pathways, maybe my mother was having more difficulty recalling very recent memories, and therefore interpreting them as having occurred further away in time than they really did.

Such an interpretation would also explain our perception of the present: it would be the interval between experience, memory creation and initial recall – the track that Laura Spinney's article was taking us down.
Matlock, Derbyshire, UK

From Leighton Jones

Laura Spinney's article provides a neurological explanation for an interesting phenomenon observed in traffic collisions. Witnesses occasionally report, with certainty, that events occurred in an order that differs from reality.

For example, they recall hearing a tyre burst, then the collision happening, when the physical evidence shows that the damage to the tyre was caused by the final impact. It has frequently been assumed that they were reconciling events into a “logical” order that fit their understanding of how such incidents unfold.

If this is how the brain works, it should sound a warning in other incidents such as firearms cases, where the question of who fired first is crucial.

Knowle, Solihull, UK

Take a deep breath

From Martin Savage

Simon Thompson mentions that parachutists yawn before they leap (20/27 December 2014, p 38). I'd imagine this has less to do



with focusing on a task, and more to do with opening their Eustachian tubes in preparation for the imminent rapid change in air pressure.

He also neglected to mention the main reason some men yawn: it's an excuse to get our arm around a girl's shoulders.
Jomtien, Thailand

Australian fires

From Scott Southurst

You write that Australia has been hit by “the worst bush fires in 30 years”, evidenced by the loss of 38 houses and more than 12,500 hectares of land to the flames (10 January, p 7).

But in February 2009 the Black Saturday fires in Victoria claimed 173 lives, with 414 people injured, and wiped out entire towns. One of those fires burned over 330,000 hectares, destroyed 1800 houses and killed 159 people.

While the recent South Australian fires are significant, especially for those affected, they are nowhere near the worst bush fires we’ve experienced in the last three decades.

Cardigan Village, Victoria, Australia

Just say no

From Isobel Hutchinson,
Campaigner, Animal Aid

If chaperon’s benefits in reducing alcohol consumption are to be proven, properly conducted human trials will undoubtedly be needed (3 January, p 8). But suggesting that the drug should first be tested on rats is nothing short of absurd.

Around 40 people have already tried the drug, so testing it on the wrong species would be a step backwards. Above all, we should take a long hard look at the ethics of inflicting suffering on animals to investigate something we already have such information on. Tonbridge, Kent, UK

Giant snowballs

From Michael Berkson

Rather than pumping fresh water across the ocean, perhaps we should consider the ideas of a former Patent Office examiner named Arthur Pedrick (3 January, p 34). He filed dozens of patent applications covering a wide variety of far-fetched inventions.

With today’s technology perhaps we should consider his patent GB 1203136, which describes an arrangement for irrigating desert areas, such as those in central Australia, by rolling snowballs from the



polar ice caps down a pipeline.

A partial vacuum in the pipe supplements the initial gravitational impetus, and allegedly so does the Coriolis effect as the pipe passes from high to low latitudes.

Great Shelford, Cambridge, UK

Conscious at a guess

From Chris Britton

Ian Beaver’s argument that machines could be considered conscious rests on the axiom that humans “are themselves calculating machines” (17 January, p 54). But humans are definitely not calculating machines.

When you catch a ball you do not calculate its trajectory; you guess it. When the ball is nearer, you guess again, hopefully better this time. Whenever you see, you have layers of guesses; you guess boundaries, guess shapes and guess objects.

Humans are guessing machines, not calculating machines. It makes a huge difference. Calculations are fragile – a slight change and the answer is completely different. Guesses are robust, can be learned, don’t require a software-hardware dichotomy and can be subject to evolution.

In the 18th century, they thought clockwork was a good model for humans. Now we think computers are. Wrong again.

Twickenham, UK

Trapped wind

From Jon Richfield

Although I am no engineer, for decades I have proposed building submarine stores of pressurised air as a source of energy. I assure Steve Orchard that they could be large enough to power whole nations for days on end (15 November 2014, p 31), that they store potential energy mainly by raising water and could recycle generated heat efficiently.

Their many merits include ecological conservation and delivery of air at practically constant pressure throughout their working capacity.

I invite readers to inspect – or challenge – a discussion of these and related proposals at bit.ly/trapped-wind.

Somerset West, South Africa

Odds in favour

From Geoffrey Withington

The Monty Hall problem is a good example of the difficulties we have in understanding probability (13 December 2014, p 32). The reason the notorious three-card scam works is likewise: most people simply aren’t well versed in the mathematics of gambling.

In this “game”, a gullible passer-by is invited to see whether they can find, for example, the queen. Three cards are placed face down and shuffled. The player stakes a pound and chooses a card.

If they lose, the dealer keeps their stake. However, if they win, the dealer only pays out an additional pound in winnings, when the payout should be on odds of 2/1, a three-pound return. These odds mean players will lose more rounds than they win and

this, coupled with paying out lower winnings, keeps the dealer in profit.

In the Middle East, a “gully gully man” would board moored ships along with merchants selling their wares. He would do the same thing using three walnut halves and a dried pea beneath. I remember seeing one man using three upturned beakers, beneath one of which would be a day-old chick.

If your colleagues are willing, try this trick on them. After half an hour, you will have scammed your lunch money.

Bridge, Kent, UK

Using your nut

From Lois Pryce

Intelligence is a slippery and elusive thing to define, as Anil Ananthaswamy’s article on plant intelligence (6 December 2014, p 34) shows.

However, in the context of living creatures I would define intelligence pragmatically as an appropriate, non-mechanical survival response to an ever-changing environment.

This seems to cover the case for plants as well as other organisms. Bristol, UK

For the record

■ **Rats! It was these, not mice, walking the treadmill in Adam Foster’s experiments into animal adaptation (17 January, p 26).**

■ **A character defect appeared in our article on personality and health: we misspelled the name of immunologist Daniel Davis (24 January, p 10).**

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FEAR may, sometimes, best be tempered by focusing on a new fear. This may even be the hidden editorial policy of some publications whose every article could be prefaced: "Be very afraid, Middle England..." In any case, whatever dire threats present themselves this week, Feedback hopes you appreciate the opportunity to distract yourself by worrying about the apocalypse coming at the end of June. Virtual apocalypse, anyway.

We were looking up when a "leap second" is going to be inserted this year, to get hyper-precise atomic clock time back in sync with the rotation of our planet. We were startled to find our search results dominated by this from CNN Money: "This year's Y2K: 'Leap second' threatens to break the Internet".

"Y2K" is, of course, a reference to the millennium bug that might have destroyed civilisation, had it not been sorted out by recoding computer date arithmetic before we reached the year 2000. That made it a classic meme for

those who argue that predictions of doom are bunkum, forgetting that it was precisely because action was taken that we're still here. Similarly, the ozone hole isn't as deep as it would have been without action.

SOMEONE at CNN seems to have shown some self-awareness in the report about the threat of the leap second, mentioned above. When we got to the end of the story we read: "Related: Poodles are attacking the Internet." Or, given how such links are often automatically generated, could it be that something, not someone, at CNN is emulating self-awareness?

NOW may be the time to start worrying about the 2038 problem. At 03:14:07 on 19 January of that year, the "long integer" data type used by Unix-flavoured computer systems to store the time and date will reach its maximum and "wrap around" to a

negative value. Disappointingly, from a narrative point of view, it seems that many systems will interpret this as a date in December 1901 rather than as a negative time. But it's still easy to imagine the havoc this might cause.

At least we know to start now on sorting out databases that have to deal with events after 2038, like pensions systems, and - perhaps most difficult - systems hard-coded into machinery.

WHAT should we call the phenomenon of old news stories resurfacing as if they are current, we asked (29 November 2014). We are replete with suggestions to supplement our "revenant news".

Colin Reynolds reports that he has had a reversion, but what it was has not yet come back to us. William Rees went biblical on us with "Lazarus stories".

David Muir suggests that anachronism is perpetrated by regurgitators. We suspect that's an entirely different kind of repeat.

Andy Johnson-Laird thinks such stories are "déjà lu" - meaning already read. The term recalls, of course, the interesting phenomenon of déjà vu (20/27 December 2014, p 8). This line of thinking leads him to consider when wine might be "déjà bu". We're not going there.

Tony Kline points out that such items are retrospective reads of worn-out old news. Conveniently, that would be contracted to "ret-reads" and then to "retreads".

And a colleague who proofread our original piece promised to tell us their idea. "Any minute now... here it is: 'newmerang'."

We feel certain we shall be returning to this question.

FEEDBACK mentioned that the image on a sign directing tourists to the UK's National Space Centre appeared to be of a Nazi V-2 rocket (6 December 2014). That reminded James Hamilton-Paterson that, to his eye, signs warning UK drivers of aircraft noise seem to feature the silhouette of a groundbreaking triumph of British

aerospace technology - the Comet Mark 1, the world's first commercial jet airliner. We agree.

Unfortunately the DH 106 Comet 1s turned out to be more groundbreaking than intended. Metal fatigue was the reason they kept falling out of the sky, pioneering investigators found. Could this, perhaps, be why it seems to feature on a sign warning of noisy incoming aircraft?

FINALLY, the UK government now has a "Digital Catapult". With a staff of 40 in trendy offices near King's Cross in London, it is on a mission "to rapidly advance the UK's best digital ideas". A colleague went along to hear a battery of engineers debate the future of television.

The subject of curved screens came up. Do they really improve viewing as much as the manufacturers would like us to think? Or do they just make it



more difficult for several people to watch at the same time?

The massed brainpower seemed happy to agree with the throwaway comment from Chris Johns, chief engineer at broadcaster Sky: "They make it easier to move big-screen TV sets round corners."

You can send stories to Feedback by email at feedback@newscientist.com. Please include your home address. This week's and past Feedbacks can be seen on our website.

Bernard Liengme's Windows 8 system welcomed him to his new year: "Friday January 2, The Day after New Years Day (Quebec)" So what was it in other parts of that Canadian time zone?

Ray bands

I am an Australian merchant naval officer and in the Southern Ocean we see some spectacular sights, but on 22 June 2014 at sunset I saw a phenomenon that I have rarely seen. Rays of light were emanating from the horizon at 180 degrees from the setting sun (see photo). Can anyone explain this quirk of nature?

■ The phenomenon seen by your correspondent is not rays of light emanating from the horizon, but the reverse: rays of shadow apparently converging. They are called anticrepuscular rays, and are the result of the setting sun – behind the observer – casting shadows from clouds.

We are all familiar with the sight of the sun illuminating broken clouds from behind, resulting in characteristic sunbeams. These sunbeams are parallel and only appear to spread out because of our perspective from the ground. The process is identical to the way parallel railway tracks appear to converge as they recede into the distance.

Close to sunset, the light rays and cloud shadows will be cast almost parallel to Earth's surface, so can continue for many miles. Dust or mist in the air can reveal the path of light and shadow disappearing into the distance behind us, converging on a point exactly opposite the sun. This is the anti-solar point.

At sea level the phenomenon will only be seen at sunrise or sunset. However, if you are high



enough, your anti-solar point will be above the visible horizon, giving you longer to experience this effect. So mountaineers and pilots like myself will have far more chance to see them. Mountaineers occasionally have a shadow display of their mountain range cast behind them while the sun is low in the sky.

Martin Powell
Westgate-on-Sea, Kent, UK

Deposit account

Our family of five eats essentially the same meals and lives in the same environment, yet our faeces have different and identifiable smells depending on the individual. This must be to do with whatever lives in our intestines. But what is it?

■ The characteristic odour of faeces is almost entirely due to

the presence of minute quantities of aromatic nitrogen compounds, such as pyridines, pyrazines and indoles. These are present in varying proportions in the faeces of different individuals and constitute a sort of olfactory fingerprint.

As writer G. K. Chesterton noted in *The Song of Quoodle*, the human nose is notoriously insensitive compared to most mammals.

However, it is extremely sensitive to these particular compounds, enabling us to distinguish our own faeces, containing microflora to which our bodies are accustomed, from those of other people or animals, which may contain dangerous pathogens. This is why we find the smell of our own stools and flatulence relatively inoffensive, while those of other people are nauseating.

Interestingly, the perfumery industry takes advantage of this sensitivity, using trace amounts of these compounds to add piquancy to its products.

Roger Savidge
Shoreham-by-Sea, West Sussex, UK

This week's questions

NO SCRAPING, PLEASE

When I touch big sheets of polystyrene insulation I get a horrible feeling, like when someone scrapes their nails down a blackboard. I cringe and shiver and feel very cold. Even thinking about it makes me squirm. Why is this?

Ben Steele
Southport, Merseyside, UK

HEART TO HEART

Why do animals have organs? Surely it would be more efficient and robust for us to have a thousand tiny hearts distributed round our bodies rather than one big one in the middle?

Adrian Bowyer
Foxham, Wiltshire, UK

SPIN DOCTORS

Many science fiction writers have suggested designing a space station that spins to generate artificial gravity. Yet this idea has not been translated into reality, nor does it seem there are any plans to do so. Why not?

Michael Parsons
Griffith, New South Wales, Australia

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